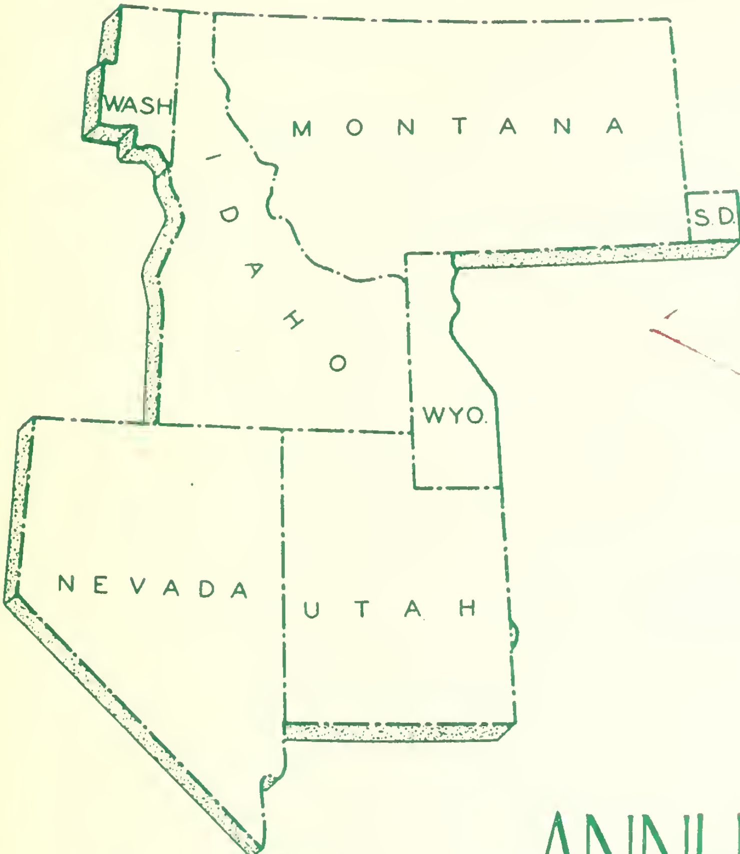

ANNUAL REPORT 1954

INTERMOUNTAIN FOREST & RANGE EXPERIMENT STATION

FOREST SERVICE
U. S. DEPARTMENT OF AGRICULTURE

OGDEN, UTAH

REED W. BAILEY
DIRECTOR

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A YEAR OF ADJUSTMENT

1954 will be remembered by us of the Intermountain Forest and Range Experiment Station as a year of many changes and personnel shifts. It certainly has been a period of adjustment. Some of the changes have come about as a result of the consolidation of the Northern Rocky Mountain Forest and Range Experiment Station at Missoula, Montana with the Intermountain Forest and Range Experiment Station at Ogden, Utah. Some have resulted from the transfer of forest disease research and forest insect research activities from other bureaus of the Department of Agriculture to the Forest Service. Others have resulted from the transfer of range revegetation and plant control research away from the Forest Service.

The original announcement late in 1953, that these reorganizations would take place, was received with mixed feelings. This was to be expected: each group that was to be combined into this enlarged station had acquired considerable stature in its own field and region. Time alone will tell us the effectiveness of this new combination in comparison with the old arrangement. However, a year of testing and self-inspection permits us to see the probable long-range effects of this reorganization and, in the main, they look good.

These changes have unquestionably resulted in a stronger research organization. Our experience, even in this short time, encourages us to believe that the present program will result over the years in more efficient, better coordinated, and better balanced research. Reorganization has, of course, created certain disadvantages. One of the more obvious is that the enlarged territory of nearly 300 million acres increases the amount of travel to be done by the director and some of the division chiefs. However, disadvantages such as this are more than offset by the increased economy and efficiency of the new setup.

The problems of managing and developing wild lands are both diverse and complex. The benefits from one line of research in this field tend to be limited by the degree of progress in other lines of research. In most cases efficient and economical research calls for the simultaneous, balanced application of several different skills--the team approach. In this respect we gained strength from the acquisition of forest disease and forest insect research. With entomologists and pathologists on the staff, we are in a better position than before to take the team approach to wild land problems. It would be difficult to improve on the fine research done by the old Division of Forest Pathology of the Bureau of Plant Industry, Soils, and Agricultural Engineering, or on the equally fine insect control research by

the Bureau of Entomology and Plant Quarantine. Nevertheless, the addition of these staffs to the station will, I think, be to the advantage of their work as well as the work of other divisions.

The moves of the past year have also served to strengthen us in another way. We now have a better distribution of research personnel in relation to the job to be done than ever before. For instance, we have, for the first time, a research program in Missoula for the purpose of studying the extremely important watershed management problems in the Columbia and Missouri River Basins. Forest management research has been strengthened at Boise. With the employment of a soils expert at Spokane, the attack on the elusive pole blight disease of white pine will be strengthened, and all phases of forest and range research will be advanced as we acquire needed information on forest soils. All in all, the shifts within the station and the additions to the station staff have given a better balanced program than was possible before reorganization.

Experiment stations, like all other organizations, must watch overhead costs. The changes of the past year have helped us in that regard, reducing the proportional load of overhead or administration costs. This means, of course, that a higher percentage of the research dollar is now going into actual on-the-ground research.

The enlargement of the station territory permits us to combine, to best advantage, the local and regional approaches to forest and range research. I believe that in the long run this may prove to be the outstanding gain to come out of the recent reorganization. During the past decade the Forest Service has established many research centers as branches of the experiment stations. This decentralized approach has proved to be a particularly effective mechanism for the type of research we do. Among other things the localization of the experiment station activities has enabled the individual researcher to develop an intimate acquaintance with his own territory and its problems. It has also facilitated the team approach to local problems. These advantages are extremely important.

Consolidation of the two stations permits better coordination--coordination not only to avoid duplication of effort in widely scattered activities, but also to be sure that in the aggregate the research program is well balanced. Many of the forest and range types and problems in the Northern Rocky Mountain Station's territory are similar to those in the territory of the old Intermountain Station. Take ponderosa pine, for example; an important timber species in both regions. The two stations attempted, and largely succeeded, to coordinate their research relating to ponderosa pine. It is apparent, however, that the attack on ponderosa pine problems and on other problems

of broad geographical occurrence is going to be easier to coordinate under the new setup than it was before. For example, we are going to be able to do a better job of relating the forest management activities in the Boise area with those in the territory of the Spokane Center. Range research at the Great Basin Work Center will augment the range studies out of the Missoula Work Center rather than duplicate them. Some of the principles of hydrology relating to forest and range lands developed at the Wasatch and Great Basin Research Centers will apply to watershed problems in Montana and northern Idaho. With intimate knowledge of these principles, research efforts at the Missoula Center in watershed management can operate directly and effectively to the solution of specific local problems.

While coordination and leadership help bring the best out of any organization, the quality of that "best" lies in the capacities of the personnel themselves. Much of my enthusiasm stems from the knowledge that the researchers of the Intermountain Station are of outstanding caliber. That bodes well for the future.

In pointing to the progress, it would be a mistake if I gave the impression that there are no inadequacies in our program. Even when we consider the total research effort being applied to the problems of forest and range lands in our station territory--the work of state agricultural experiment stations, universities and colleges, industry, and all Federal research agencies--and weigh it against the needs, it becomes apparent that in a number of fields present research is not commensurate with the problems. Let me illustrate with two examples.

In realigning our research, I have become very conscious of a need for expanding our economic studies. The Intermountain country has only begun to develop and it has a great future ahead of it. However, in all technical aspects of wild land management--range, watershed, forestry, fire control, disease control, insect control, and utilization--we are plagued with economic problems which, if left unsolved, will hold up progress. These economic aspects need a great deal more attention than we are giving them now.

Another example deserving emphasis is the inadequacy of our research in watershed management. As I said before, we have recently stationed a watershed researcher at Missoula. However, the problems there warrant the attention of more than one man. The Missoula Research Center territory lies at the headwaters of two great river systems. What happens to these headwaters is of vital concern to a large part of the United States. Farther south in the Colorado River country, the states and Federal Government are planning for a multi-billion dollar water development program. Yet the station so far has lacked the resources to tackle the extremely important sedimentation problems in this basin which properly ought to govern management and use of its forest and range resources.

An investigative organization such as ours can pretty well feel the pulse of progress in the questions we are asked. It is significant, therefore, that the tempo of questioning has stepped up considerably in the past several years. We can attribute this situation largely to rapid population growth and increased demand for resources. Though we take great pride in our accomplishments, it is less comforting to measure what we are doing against the great need for information. We plan to devote considerable attention to the matter of developing a research program adequate in all its phases and will have more to say on that score in another year.

The job of organizing for research in such a big diverse, and important country as the northern Rocky Mountain and Intermountain regions has been a real challenge. We have, I think, made encouraging progress. With the staff that is now assembled here, I am confident that we can continue to do so.

REED W. BAILEY
Director

FOREST MANAGEMENT RESEARCH

Forest management may be described simply as the systematized growing of timber as a crop. Research by the Forest Service in this very core of forestry includes nationally six major work projects:

1. Silviculture (basic tree studies, cultural measures in young stands [intermediate cuttings], and harvest cuttings).

2. Management (application of business methods and technical forestry principles to a forest property).

3. Mensuration (measurement of trees, stands, and products).

4. Forest regeneration (establishing new forests by natural or artificial means).

5. Naval stores (production of resin and turpentine).

6. Forest genetics (improvement of trees and stands by selection and breeding).

The program of the Intermountain Forest and Range Experiment Station now includes investigations in all fields outlined above except naval stores; this work is confined to the southeastern states.

What are the most urgent problems of forest management towards which the Intermountain Station should be directing its research efforts? Primarily, we must learn how to cut for maximum growth, minimum mortality, and prompt regeneration of desired species in the following forest types: ponderosa pine, western white pine (and associated species), western larch-Douglas-fir, lodgepole pine, Engelmann spruce-alpine fir, Jeffrey pine, and aspen. Closely allied to harvest cutting is the problem of artificially regenerating poorly stocked burns and cutover areas. In many cases this involves site preparation of one kind or another. Of considerable urgency, also, is the need to know how to manage extensive second-growth stands of ponderosa pine, white pine, and other commercially important species. Included here are intermediate cuttings.

Underlying the important problems just listed is the need for basic studies designed to increase our silvical knowledge of the tree species of the Intermountain area and provide greater understanding of ecological succession as affected by fire and other disturbances. Also needed are mensurational studies to yield more accurate information on the volume and growth of most of our forest types.

Some of the most perplexing problems facing the forest manager today cut across divisional lines. Serious diseases like pole blight and blister rust of western white pine, and insects such as the bark

beetles, pine butterfly, and spruce budworm call for the coordinated efforts of silviculturists, pathologists, and entomologists. The Intermountain Station is in much better position to provide this concerted attack as a result of the recent reorganization.

During 1954, the first year of consolidation, the Forest Management Research program of Intermountain Station was appraised critically, and its forces were realigned to achieve better balance. This move was aided by a small increase in the funds allotted to the Station for genetics research in the development of a blister rust-resistant western white pine. It permitted an increase from one-half man's time to one and one-half man's time on forest genetics projects.

Improved balance was attained by the following distribution of effort:

Missoula Research Center. Primary research for the Station in western larch-Douglas-fir and lodgepole pine, with minor work in Engelmann spruce-alpine fir. Supplemental research in ponderosa pine.

Inland Empire Research Center. Primary research in western white pine (including genetics) and related species. Supplemental research in ponderosa pine.

Boise Research Center. Primary research in ponderosa pine, the most universal of the commercially valuable trees in the Intermountain area.

With the above organization it is felt that we can go farthest towards solving the problems of the region. While some time was sacrificed during 1954 in personnel moves and reassignments caused by program adjustments, it will be more than offset by future gains. Furthermore, if research in forest management is strengthened in the future, it can be built effectively upon this framework.

Forest Management Research at the Intermountain Station in 1955 will operate along the general lines established in 1954. Greater emphasis will be placed on regeneration by assigning a man from the Division in Ogden to push this important project. He will spearhead investigations in regeneration (natural and artificial) in all types, but with major emphasis at the start on ponderosa pine.

SILVICULTURE AND MANAGEMENT

Ponderosa Pine Production

A concerted effort to complete the installation of the ponderosa pine production study on the Boise Basin Experimental Forest on schedule

continued through the 1954 field season. Because the second replication consisting of 8 compartments totaling 402 acres was designed to include the same combinations of logging methods, marking methods, and levels of reserve volume employed in the first replication, procedures were the same as described in the 1953 Annual Report for that installation.

Other work accomplished prior to logging included the surveying of all spur roads of the first replication to allow revision of experimental forest maps and to permit exclusion of road area from acreage and volume calculations within compartments.

The season's logging operation started early in October. The construction of 2.4 miles of spur roads completed the total of about 7.2 miles of such roads for all compartments. Felling the season's cut of 1.9 million feet was completed in mid-November and skidding was finished in early December. About 500 M bd. ft. have been loaded out and hauling of the remainder is expected early in January 1955.

Slash disposal has been completed for all compartments. Erosion control measures (cross ditching, and road and fill reseeding) have been completed as far as weather conditions have permitted. Because logs still remain in six compartments for winter hauling and because of frozen ground, it is expected that temporary dikes instead of cross ditches will be constructed on roads which are still open. These dikes will be replaced by cross ditches next spring or summer.

Results of this study to date will soon be made available through publications on felling and skidding costs, stand structure, logging damage, saw tree mortality, and sawtimber growth.

Logging Costs in Light Partial Cuts of Ponderosa Pine

Frequent light cuts appear to be economically feasible in ponderosa pine stands, to judge from a logging cost study made in a light experimental cutting. A cut in Lick Creek drainage on the Bitterroot National Forest, removing only 2,260 bd. ft. per acre, cost \$24.50 per M bd. ft. log scale loaded on trucks. A total of 500 M bd. ft. of timber was involved in the study. The cost compares favorably with Region One's cost guideline value of \$26.63 when the latter is adjusted to a comparable basis of 2,260 bd. ft. cut per acre, 10 logs per M bd. ft., and a moderately easy logging chance. The individual cost elements are compared in table 1. The cost of felling, bucking, and skidding were somewhat higher than regional cost check figures, while the developmental costs were substantially lower.

Table 1.--Comparison of costs per M bd. ft. log scale between Lick Creek light partial cut and regional cost guideline

Elements	Lick Creek	Regional cost guideline
Development: Roads, skidroads, landings	$ 5.38	$ 8.40
Felling and bucking	3.86	2.90
Skidding	8.90	7.08
Supervision, administration, social security, etc.	3.10	4.56
Loading	1.76	2.19
Slash disposal	1.50	1.50
Total	$24.50	$26.63

Mortality Following Partial Cutting of Western White Pine

Mortality during 5 years following partial cutting of a mature western white pine stand was closely related to tree vigor. Residual trees were rated for crown vigor following a 50-percent cutting on Swede Creek in the Clearwater National Forest. Five-year records of mortality are summarized in table 2.

Table 2.--Mortality in relation to vigor class of western white pine 5 years after partial cutting

White pine vigor class	Stand per acre after cutting		5-year mortality		Mortality percentage	
	Trees	Volume	Trees	Volume	Number of trees	Volume
	Number	Bd. ft.	Number	Bd. ft.	Percent	Percent
Good	8.1	7,544	0	0	0	0
Fair	10.5	6,374	0.5	132	4.8	2.1
Poor	4.4	1,715	9	258	20.5	15.0
All classes	23.0	15,633	1.4	390	6.1	2.5

None of the white pine trees originally rated as having good vigor died. Two percent of the board-foot volume contained in fair vigor trees and 15 percent of the volume in poor vigor trees have been lost to various mortality agents in 5 years. These results agree with those from other tests of partial cuttings in relatively vigorous white pine stands on the Coeur d'Alene and Kaniksu National Forests. They again

point up the possibilities of selection on a vigor basis in partial cutting of mature western white pine.

Ribes Control Tests

A portion of the Deception Creek Experimental Forest is being devoted to tests of ribes control in cooperation with the Division of Blister Rust Control. Three units are involved in the study:

1. A clear-cut unit on a north-facing slope on which the ribes were sprayed with 2,4,5-T in 1954. Western white pine trees will be planted after eradication of ribes. Part of the unit will be planted to trees produced by the blister rust-resistant white pine breeding project.

2. A seed-tree unit on which an unmerchantable western hemlock understory was felled and the slash piled. It is expected that this unit will reseed naturally to white pine after ribes control by broadcast spraying with 2,4,5-T.

3. Another clear-cut unit similar in treatment to (1.) above to be established on a south-facing slope.

Installation of the study will be completed within the next 2 or 3 years.

Effect of Understory Trees Upon Diameter Growth of Residual Larch

On the Coram Experimental Forest in mature and overmature western larch, release from initial reproduction cuttings increase postlogging diameter growth of the residual trees 67 percent over prelogging growth in the first 5-year period. A further increase of 2 percent was noted in the second 5-year period. Even more significiant is an additional increase of 36 percent which resulted from the removal of undesirable species from the understory. These increases brought average diameter growth to 0.62 inch per decade in the second 5-year period following cutting as compared to 0.30 inch per decade before cutting.

Treatments in this study included no treatment (control), mechanical scarification, broadcast burn after slashing small trees, and understory slashed and burned in piles.

The data help to point out a strong reason why response of larch to logging release is poor. Larch stands are usually succeeded by more tolerant species, such as Douglas-fir, alpine fir, western hemlock, and western redcedar. These understory trees limit the growth response of overwood larch through competition for available soil

moisture. Where the understory trees are thinned by bulldozer in seedbed preparation, some release is also given the overstory trees supplemental to this work.

Tree Vigor and Douglas-Fir Beetle Attacks

A study of the relation between tree vigor in Douglas-fir and attack by the Douglas-fir beetle indicates that low-vigor trees are most susceptible to attack under endemic conditions, but that under epidemic conditions high-vigor trees may be equally susceptible. A total of 186 beetle-infested trees and 920 adjacent uninfested trees on the Kaniksu, Coeur d'Alene, St. Joe, and Clearwater National Forests were observed and classified according to tree vigor. Region One of National Forest Administration cooperated in the project.

Susceptibility indexes were calculated using the following formula:

$$\text{Susceptibility index} = \frac{\text{Percentage of infested trees in given vigor class}}{\text{Percentage of given vigor class trees in stand}}$$

The resulting values by tree vigor class for each of the four national forests are given in table 3. Stands studied on the Kaniksu

Table 3.--Susceptibility index by tree vigor and intensity of infestation

National forest	Tree vigor class		
	Good	Fair	Poor
Endemic infestations			
Kaniksu	0.091	0.805	2.462
Clearwater	.462	.621	1.310
Epidemic infestations			
Coeur d'Alene	1.333	.884	1.000
St. Joe	1.733	.739	1.026

and Clearwater National Forests contained relatively light beetle infestations. Susceptibility indexes for these forests show a parallel relation to tree vigor. In stands studied on the Coeur d'Alene and St. Joe National Forests, infestation by the Douglas-fir beetle was in an epidemic stage. Here the susceptibility indexes showed little relation to tree vigor.

Results from this limited study suggest that Douglas-fir beetle infestations build up in the low vigor trees of the stand and then, when large numbers of beetles are present, all vigor classes are likely to be attacked.

Lodgepole Pine Research in the Intermountain Region

During the years 1952 to 1954, inclusive, the Intermountain Station through the cooperation of Region Four of the Forest Service carried on a study of the status of lodgepole pine management in the Intermountain area. It culminated this past year in a comprehensive problem analysis of the species which was released as Miscellaneous Publication No. 2 by the Intermountain Station in June. In addition to a discussion of the problems of management and a suggested list of needed research studies, the analysis includes a preliminary lodgepole pine stand classification which should be useful to forest managers concerned with this type. A separate writeup of the classification will be published soon in the Journal of Forestry.

As a result of the problem analysis on lodgepole pine in Region 4, a study was made of the viability of lodgepole pine seed retained in cones in slash and effects of cone position. Unopened cones were collected from 6-year-old logging slash on the ground and as much as 3 feet above ground.

Germination tests with extracted seed showed that (1) some seed stored in unopened cones in logging slash remain viable for at least 6 years, and (2) seed from cones above ground in this study had twice as much germinative capacity and germinative energy as seed from cones on the ground. (Germinative capacity is defined as percentage of germinable seed in a sample, and germinative energy as percentage of germination obtained in a definite period of time.) These findings give assurance that seed in logging slash can help regenerate clear-cut lodgepole pine lands for 6 years or more. It is apparent, also that the slash disposal method employed can influence the viability of seed available for regeneration.

The forester assigned to the cooperative project is now stationed at the Missoula Research Center from where he will continue investigations in lodgepole pine in the Intermountain area.

MENSURATION

Growth of Young Ponderosa Pine Stands

Stands of second-growth ponderosa pine are reaching the lower limits of merchantability in many parts of the West. To manage these young stands wisely, foresters and land owners need reliable information on their growth capacities.

A research paper containing growth tables for young ponderosa pine trees was published this year. The tables show predicted 10-year cubic-foot-volume growth for individual trees by age and diameter class. Applied to a stand table for any particular forest property, they will give accurate gross growth predictions for the next decade.

Mortality adjusting factors are also included which permit the prediction of net cubic-foot-volume growth. Converting factors for changing cubic-foot volume to board-foot volume and to cordwood volume are also included.

Allowable Errors in Sample Scaling

With increased interest in the use of sampling methods for volume determination in national forest timber sales, the problem of accuracy standards becomes increasingly important. Just what is a reasonable allowable error in sample scaling commensurate with timber values and scaling costs?

Because sampling errors are not reduced in direct proportion to increased sampling intensities, there is a point of diminishing returns in sampling where the increased cost of a more intensive sample is not justified by the reduction in sampling error.

A research note published this year will help to answer this question of acceptable sampling errors in sample log scaling and tree measuring. A graph alinement chart in the publication gives the most economical allowable errors for a range of total sale values, variability of volumes, and scaling costs.

Delineating Ponderosa Pine Volume and Site Quality Classes from Aerial Photographs

The installation of the experiment in ponderosa pine management at Boise Basin Experimental Forest required the delineation of 3 volume-per-acre classes of timber on the ground in each of 16 compartments totaling 847 acres. Interpretation of aerial photographs saved considerable time and effort in completing the delineation.

Subsequent 100-percent cruises of each class checked the accuracy of delineation and afforded material for a series of stereograms for volume classes between 9 and 35 M bd. ft. per acre. Suggestions for the use of stereograms in improving timberland sampling are given in a publication covering the work.

REGENERATION

Effect Upon Seed Production of Size of Larch Seed Trees

In a study on the Coram Experimental Forest 4-year seed production of scattered western larch seed trees was found to vary significantly with average size of the trees. The study was made in a seed-tree cutting in which 4 to 5 dominant mature western larch trees with well-developed crowns were reserved for seed production. A few additional trees were left to bolster up future cuts, and some were left

because they were too small to log. Seed fall was measured with conventional 1/4 milacre seed traps placed in the center of 1/5 acre plots installed to collect data on the overwood. The seed catch for a 4-year period, including the excellent crop in 1952, showed a highly significant correlation with average d.b.h. of the seed trees on each plot.

Average d.b.h. of seed trees Inches	Average seed production per tree Number
14	19,700
18	59,700
22	99,500

The seed fall from trees under 12.5 inches d.b.h. was negligible, and trees below this size should not be considered as an effective seed source. No trees above the 22-inch class were included in the study but it is likely that seed production would level off or even decrease in trees above this size. Such trees are generally decadent and have small crowns.

Seedbed Preparation for Natural Regeneration of Western Larch

That ground preparation favors natural regeneration of western larch over less desirable associated species has been substantiated by the following experiment. During the period 1943 to 1945, an extensive area of larch-Douglas-fir timber was logged in a commercial seed-tree cutting on the Coram Experimental Forest. The stand before logging was mainly mature and overmature larch, Douglas-fir, and Engelmann spruce, with minor quantities of white pine, lodgepole pine, and alpine fir. The objective was to harvest most of the crop, but reserve a small residual of 4 to 5 dominant larch trees per acre as a seed source for natural regeneration. No seedbed preparation except that incidental to logging was carried out. In 1949, it was decided to determine whether or not stocking of western larch and Engelmann spruce could be increased by various methods of seedbed preparation. The following treatments were employed:

1. No treatment (control).

2. Mechanical scarification. The ground was sacrified with a tractor-drawn Athens disk or a brush blade on the tractor.

3. Broadcast burn. Small residual trees and shrubs were slashed to provide fuel for a broadcast burn.

4. Understory slashed, piled, and burned. The understory of undesired trees and shrubs was slashed and burned in small

piles. Little additional mineral soil was exposed by this treatment, but the stand was opened to light and moisture.

Results of the treatments for the three principal species in the stand are presented in table 4.

Table 4.--Percent of milacre quadrats stocked with western larch (WL), Engelmann spruce (ES), and Douglas-fir (DF) before and after three ground treatments were applied

Treatment	Stocking before treatment (1949)			Total stocking, 1953			Net increase since treatment		
	WL	ES	DF	WL	ES	DF	WL	ES	DF
Control	28	21	48	37	27	56	9	6	8
Mechanical scarification	17	8	38	54	20	57	37	12	19
Prescribed burning	27	18	40	65	40	59	38	22	19
Slashing understory	32	13	49	42	16	55	10	3	6

In terms of net increase in stocking all species were favored by the increased exposure of mineral soil resulting from the mechanical scarification and prescribed burning. However, western larch benefited more than Douglas-fir and Engelmann spruce from these two treatments, and so gained a more favorable position with regard to its competitors.

Seedbed Preparation in Engelmann Spruce-Western White Pine

Effectiveness of methods of seedbed preparation are being tested in clear-cut blocks in the Engelmann spruce-western white pine type on the St. Joe National Forest. Personnel of the St. Joe National Forest, Potlatch Forests, Inc., the University of Idaho, and the Station cooperated in the installation of the test to compare the effectiveness of three intensities of dozer piling of logging slash with prescribed broadcast burning and with untreated areas as seedbed preparation in obtaining natural reproduction. Slash, ground surface, and plant cover were inventoried on each of 10 test plots. All treatments were completed in 1954. A heavy Engelmann spruce seed crop this past fall should give the test an excellent start.

Viability of Ponderosa Pine Seed as Affected by Origin and Storage

An analysis of germination data secured in 1950 revealed that storage method, and to a lesser extent age and altitudinal location

of parent trees, affects the germinative capacity of central Idaho ponderosa pine seed in dry storage. After 14 years, seed from young (50-70 years) open grown trees at 5,500 feet and stored at 32° F. had the highest value (74.7 percent) and seed from scattered old growth trees at the same altitude in above ground cellar had the lowest (44.7 percent). Interaction of variables was also evidenced by differences in germinative capacity for a particular origin depending on the storage method.

Banding Ponderosa Pine Seed Trees to Keep Out Squirrels

It appears more and more likely that keeping squirrels out of selected trees in partially cut ponderosa pine stands will increase seed fall appreciably. In the summer of 1953 a small-scale test of banding tree trunks as a means of controlling squirrel damage to seed crops was installed at Dunn Creek on land owned by the J. Neils Lumber Company, Libby, Montana. Five isolated seed-bearing trees per acre were selected on 11 acres and protected by attaching a 20-inch-wide metal band to the trunks at from 5 to 7 feet above the ground. A check of cone cutting on protected and unprotected trees showed that the bands were effective in keeping squirrels out of the trees.

Because protection against squirrels gives promise of increased seedfall, efforts are now being directed towards refining the techniques of tree banding.

A Poor Ponderosa Pine Seed Crop is Forecast for 1955

This prediction is based partly on data obtained in a ponderosa pine seed-crop forecasting study on the Kootenai National Forest. Examination of about 100 permanently tagged branches on 8 trees disclosed that not more than 2 cones will mature on the sample branches next fall, as compared with from 80 to 144 cones maturing on the same branches in moderately fair seed crops in the past. Casual observations on trees in the Lolo and Bitterroot National Forests point to a poor crop for 1955 in these areas also.

Regeneration of Lodgepole Pine in Clear Cuttings

The relations of seed supply, logging, and slash disposal methods to natural regeneration in lodgepole pine clear cuttings has been clarified in 5 years of study in Montana. The principal seed supply on such cuttings is contained in the persistent cones borne on the logging slash scattered on the ground by logging activities, or has been dispersed from standing trees before cutting.

The Montana studies show that few seed are dispersed beyond distances of about 2½ tree heights from the uncut bordering timber. Side seeding is effective, then, only on a fringe strip containing one-half or less of the area in the 30- to 50-acre clear-cut blocks.

Burning of all slash destroys considerable quantities of the seed and poorly stocked seedling stands result on the burned-over seedbed. Likewise, sparse stands of new seedlings develop initially on seedbeds covered by windrows of slash, but additional seedlings gradually fill in the unstocked ground. On scarified seedbed, seedlings become established abundantly and quickly. The seedlings are distributed well enough to provide a uniform forest stand, but the large number of seedlings per acre presents another problem--that of possible future overstocking.

Fire hazard reduction has been considered in connection with the slash disposal methods. Burning of windrowed and bunched slash as well as bulldozer piling of slash immediately reduced the fire hazard to an acceptable level. Where no slash disposal has been practiced or slash has been lopped and scattered, fuel ratings continue to be higher than an acceptable level 5 years after treatment.

A Small Seed Trap

The Station has developed a 1-foot-square wire seed trap useful in seed dispersal studies. The trap is simple to construct and costs only about one-fourth as much as the conventional 1/4-milacre traps. The small trap is light in weight and can be transported and placed with ease. It has been tested by two seasons of use and has withstood successfully the pressure of snow depths up to 4 feet. Results from 21 1-foot-square wire traps compared with 17 quarter-milacre traps gave almost identical estimates of the mean for the 1952 western larch seed crop with only a slightly greater sampling error in the smaller traps. The trap and its method of construction are described more fully in a manuscript submitted to the Journal of Forestry.

GENETICS

Breeding Blister Rust Resistant Western White Pines of Good Growth and Quality

For the fifth consecutive year the Station has cooperated with the Spokane Unit, Blister Rust Control, National Forest Administration, and other organizations in breeding blister rust-resistant and otherwise superior western white pines. This project has grown to major proportions, with large numbers of progenies and grafted trees produced from apparently resistant selections now under test. Early results appear promising, both in developing resistance and in improving other traits. A publication issued this year summarized techniques and early results in breeding for faster growth rate and better timber quality. Another manuscript, "Self-compatibility and effects of self-fertility in western white pine" by R. T. Bingham and A. E. Squillace, was submitted to the Journal of Forestry for publication.

As in the past the Station provided assistance in controlled pollination, growing and outplanting of progenies for resistance testing, grafting, and examination of progenies and grafted trees for symptoms of rust. Intensive measurements of growth rate and branching habit among progenies and grafted trees were continued. Some new developments, mainly concerned with breeding for vigor and quality are listed below:

1. A selective fertilization study was begun, designed to determine the extent of self-fertilization that will occur when pollen from the same tree competes with pollen of other trees of the same species. Results of this work may be important in seed orchard planning.

2. Three 10-acre plots were cleared and prepared for outplanting progeny (seedlings) for long-term study of the inheritance of vigor and timber quality. The plots are located in rust-controlled areas at Emerald Creek (St. Joe National Forest), Deception Creek Experimental Forest, and Priest River Experimental Forest. Progenies of selected crosses will be outplanted in these plots at a spacing of 8 x 8 ft. The first planting will consist of progenies (2-1 stock) from 54 cross-, self-, and wind-pollinations, to be set out in the spring of 1955. Three similar outplantings are planned for succeeding years.

3. Two small tests were installed specifically to study variation in seed weight, its effect upon first-year seedling heights, and adjustment techniques. Results are now being analyzed.

Field Tests of Hybrids

Early growth and crown form of lodgepole pine x jack pine hybrids produced at the Institute of Forest Genetics (Placerville, California) compare favorably with local lodgepole pines used as controls. The oldest trees are now 7 years from seed. In two of the three outplanting sites, the hybrids averaged 37 percent taller and 15 percent larger in diameter than local trees; in the third site they were about the same. Considerable variation in crown width relative to total height occurred among planting sites, but on the average the hybrids were slightly narrower crowned. At all sites the hybrids had fewer branches per whorl.

Seed Produced Following Controlled Pollination

Controlled pollinations made on local trees in the spring of 1953 were variable in production of sound seed. Comparative yields were as follows:

Species	Seed yields
Pinus ponderosa x P. ponderosa v. scopulorum	Good
P. ponderosa x P. engelmannii (apacheca)	Poor
P. ponderosa x P. ponderosa v. arizonica	Very poor
P. ponderosa x P. montezumae	None
P. contorta x P. banksiana	Fair to poor

One intraspecies cross and one self-pollination in ponderosa pine yielded good and fair numbers of sound seed, respectively.

OTHER

The Division assisted Timber Management of Region Four, National Forest Administration, in the design of a 138-acre spring planting trial near Idaho City on the Boise National Forest where some 65,000 acres of fine timberland are unproductive as a result of past uncontrolled fires. Variables of ground preparation and ponderosa pine stock were employed in combination, with allowances made for additional variables of competition and aspect if desired.

First-year results are encouraging although favorable weather may have played a deciding role. Statistical analyses of year-end survival indicates highly significant differences between the variables employed and interaction between them. It is planned to continue these plantings for at least 4 more years.

The Intermountain Station served as host for a meeting at Boise, Idaho, of personnel engaged in ponderosa pine research at the western forest and range experiment stations. Timber management divisions from the western regions of National Forest Administration were also represented. All phases of management were discussed. This conference should be most effective in coordinating research effort throughout the range of ponderosa pine.

RANGE MANAGEMENT RESEARCH

When last year's annual report was being written, most of the range research formerly carried on by this Station in artificial revegetation and in noxious plant control was in process of being transferred to the Agricultural Research Service. The year has seen these changes effected. This work is now being carried on under the able field supervision of Mr. A. C Hull of Agricultural Research Service, whose extensive experience in range research in Utah, Nevada, Idaho, Wyoming, and Colorado was gained as a former member of the staffs of both the Intermountain and Rocky Mountain Forest and Range Experiment Stations. Mr. Hull's familiarity with western range problems insures that the research in his unit will be effectively directed.

A major effort in the Division of Range Research has been to complete manuscripts in artificial revegetation and plant control that were in process of preparation or were ready to be undertaken at the time of reorganization. These include one on seeding rangelands in the Intermountain area for an Agricultural Handbook by Plummer et al.; one on species adaptability and seeding season in northeastern Washington for a Station research paper by Evanko; and two manuscripts, one on seeding rates for crested wheatgrass, and one on the effects of 2,4-D on species associated with big sagebrush, for the JOURNAL OF RANGE MANAGEMENT by Blaisdell and Mueggler. In addition, USDA Farmers' Bulletin 2072, "Controlling Sagebrush on Range Lands," and a revised edition of Farmers' Bulletin 1948, "Sagebrush Burning--Good and Bad," by Pechanec et al., were published in 1954.

In order to bring up to date and make available results of artificial revegetation research that this Station has carried on in southern Idaho, Mr. Hull is collaborating with Ralph C. Holmgren of the Boise Research Center and with the University of Idaho, in making a final reexamination of field trials of species adaptability and methods in artificial revegetation. A preliminary survey was made in the fall of 1954, and it is expected to complete the field work on this joint project during the summer of 1955.

NATIVE SUMMER RANGE

Cattle Gains

For the past several years, the Vigilante Experimental Range in the upper Ruby River Valley of southwestern Montana has been conservatively stocked with cattle for approximately 5 months, June through October. Fairly uniform grazing has been secured by the naturally well-distributed water supply, supplemented by a good salting program and considerable riding.

Gains made by cattle on this summer range have compared favorably with gains made on cultivated pastures and even in feedlots. Steers, heifers, and dry cows have made average gains of between 2 and 3 pounds per day from early June until late September when they were removed from the range and sold as beef. Records for the entire 5-month grazing season are available for only a few animals, but these indicate that the same rate of gain did not continue through October.

Current cattle weights followed a pattern similar to that of past years. During the first 108 days (6/12-9/27), yearling steers and heifers on the Vigilante range gained an average of 2.5 and 2.2 pounds per day, respectively. For the entire grazing season of 138 days (6/12-10/27), however, steers averaged 1.8 pounds per day and heifers 1.6 Apparently good gains can be expected while the forage is green and succulent, but after it is mostly dried, weight losses occur, or at best rate of gain is greatly retarded.

Salt Consumption by Cattle

Average salt consumption during the 138-day grazing season per head of mixed cattle (calves excluded) was 4.69 pounds. Use by months was as follows:

Month	Pounds per head
June (19 days)	0.29
July	.79
August	1.59
September	1.14
October (27 days)	.88
	4.69

Contrary to general belief, the demand for salt appears to be considerably greater during late summer and fall than in spring and early summer. Because of changes in herd composition September 27, the apparent reduction in amount used during October may not be significant. A similar pattern of use in the past 6 years, however, indicates that salt consumption is actually light during the early part of the grazing season, heavy during the middle part, and intermediate during the latter part. During the past season approximately 20 percent of the block salt was lost through weathering.

Response of Forbs to Clipping

Generally speaking, proper use for a forage species is the degree of use which allows that species to produce the maximum amount of herbage consistent with the maintenance of sufficient vigor and ground cover to insure soil stability. It would be a great help to the range manger if he had a reasonable approximation of proper use, a rough guide, that he could apply to key species. Such guides have

been established for some grasses and a few browse species, but we know little about the reaction of forbs to different degrees of utilization. This is surprising in view of the fact that forbs provide a large portion of the forage on summer ranges.

In an attempt to add to our knowledge of proper use a study was initiated in the summer of 1950 which included the clipping of five species of forbs, *Valeriana edulis*, *Geranium richardsonii*, *Ligusticum porteri*, *Castilleja linariaefolia* (red castilleja), and *C. sulphurea* (yellow castilleja). Groups of 6 of these plants were clipped in the flowering stage each year for 4 years at intensities of 50, 75, and 90 percent of current growth, and an unclipped group in each species was included for comparison. In the case of the castillejas growth was measured and removal accomplished in terms of inches, whereas green weight in grams was used for the other three species. The initial differences between treatment groups were adjusted by covariance analysis.

Only two of the five species, valerian and geranium, showed differences between adjusted mean weights or lengths that could be attributed to treatment (table 5). Both valerian and geranium

Table 5.--Adjusted herbage production of forbs as affected by clipping, together with variance ratios (F) and least significant differences, 1954

Species	Treatment				(F)	Least significant differences	
	Un-clipped	50% clipped	75% clipped	90% clipped		0.05	0.01
Valerian (gm.)	124	97	55	39	1/8.37	40	54
Geranium (gm.)	156	103	63	42	1/5.05	65	89
Ligusticum (gm.)	124	161	124	106	.62	--	--
Red castilleja (ins.)	46	82	70	31	1.97	--	--
Yellow castilleja (ins.)	90	51	58	72	.58	--	--

1/ Highly significant

showed a graduated response to treatment and highly significant differences between the 75 percent clip and the unclipped, and between the 90 percent clip and the unclipped. In addition, in the case of valerian, the differences between the 50 and 90 percent clip and the 50 and 75 percent clip proved to be highly significant and significant, respectively. In neither instance was the difference between the 50 percent clip and the unclipped large enough to be significant.

It is apparent from table 5 that utilization of valerian and geranium resulting in removal of three-fourths or more of the current growth will cause a substantial reduction in herbage produced. It is also probable that removal of half the current growth of these two species each year for several years will reduce their production of herbage, although for the 4-year period covered by this study the effects are not statistically significant. On the basis of these findings it may be concluded that proper use of valerian and geranium is approximately 50 percent or less. Even 50 percent use during the bloom each year may be detrimental over a period of many years.

There was no graduated response to treatment with ligusticum and the castillejas. Although there is a suggestion of stimulated growth from some treatments, none of the differences found were significant. For effects of treatment to be discernible in these species the study would have to be carried on over a longer period or larger numbers of plants would have to be used.

SEEDED SPRING-FALL RANGE

Cattle Gains

Following tests to find species adapted for range seeding in northeastern Washington, five 6-acre pastures were fenced from an area of abandoned marginal cropland on the Bremner Ranch, near Republic, and four were seeded, each to a different species, in the spring of 1952. Now herbage production of intermediate wheatgrass, crested wheatgrass, pubescent wheatgrass, and smooth brome are being compared with production of weedy species on the adjacent untreated pasture.

Grazed for the first time in 1954, the seeded species have shown their superiority in providing early spring forage. Despite unfavorable growing conditions, intermediate wheatgrass, crested wheatgrass, pubescent wheatgrass, and smooth brome leafage averaged 4.9, 4.0, 4.0, and 4.3 inches in height, respectively, on May 2 when the pastures were stocked, compared with 1.0 inch for cheatgrass on the untreated area. Early growth and a large volume of forage are of most importance to the operator during the spring between winter feeding and the opening date for grazing on national-forest summer ranges.

Results of the 1954 test are shown in table 6. Intermediate wheatgrass, which developed most rapidly and provided most forage, furnished the greatest number of animal-days' use. Crested wheatgrass ranked second. Pubescent wheatgrass ranked third chiefly because in this test a spotty stand was obtained. Despite this poor stand, herbage production of pubescent compared favorably with that of crested, suggesting that it would have ranked ahead of crested wheatgrass if a good stand had been obtained. Of the species seeded, smooth brome was considered least desirable because of its relatively low productivity early in the season.

Table 6.--Animal days of use, animal gains, and herbage production on seeded pastures, Bremner Ranch, 1954

Pasture	Cow-calf use	Total gains: Cows	Total gains: Calves	Herbage production: Through grazing period	Herbage production: After grazing period	Herbage production: Total
	Days	Pounds			Pounds	
Intermediate wheatgrass	144	560	240	1,454	1,047	2,501
Crested wheatgrass	96	420	170	771	932	1,703
Pubescent wheatgrass	78	390	145	538	1,059	1,597
Smooth brome	78	195	125	489	1,162	1,651
Unseeded (Cheatgrass	--	--	--	63	248	311
(Forbs				264	322	586

Production of cheatgrass and forbs was both low and late. Cheatgrass produced less herbage over the entire season than smooth brome produced during the early spring period. This small amount of herbage precluded stocking the control pasture this year. Although cheatgrass provides good livestock forage under favorable conditions, it is difficult to manage a livestock operation on this basis.

The Bremner pastures corroborate results from elsewhere that seeding early spring and fall ranges now in cheatgrass to adapted perennial species will help stabilize the livestock operation and also result in greater yields of livestock products.

Palatability of Seeded Grasses

In 1950 grazing was started at the U. S. Sheep Experiment Station, Dubois, Idaho, on a study designed to provide information on the palatability to sheep of 10 grass species. Three of these are wheatgrasses native to this country--bluebunch, bluestem, and thickspike wheatgrass--and the remaining 7 are popular introduced species--intermediate, pubescent, Fairway crested, standard crested, Siberian, and tall wheatgrass, and Russian wildrye. These grasses were planted in replicated plots on a silt loam soil of basaltic origin in the 11-inch precipitation zone. Good stands were obtained of all species before the grazing treatment began, with the exception of native bluebunch wheatgrass which produced no better than a fair stand.

Table 7 gives the 4-year average of annual production by species. It is interesting that of the native species only bluestem wheatgrass has shown the degree of productivity achieved by some of the introduced wheatgrasses. (The low productivity shown for bluebunch wheatgrass, however, is partly a result of the fact, already noted, that a good stand of this species was not obtained.) These production figures differ in some respects from results on spring-fall

Table 7.--Average annual production and spring utilization by sheep, in pounds per acre, air-dry, of 10 grasses, together with least significant differences for utilization

Species	Total production		Spring utilization
Intermediate wheatgrass	902		180
Pubescent wheatgrass	957		152
Fairway crested wheatgrass	858		107
Standard crested wheatgrass	921		105
Russian wildrye	649		101
Siberian wheatgrass	855		87
Tall wheatgrass	622		52
Bluestem wheatgrass	928		34
Thickspike wheatgrass	510		30
Bluebunch wheatgrass	380		13
		LSD(t.01)	68
		LSD(t.05)	50

range in central Utah (1951 Annual Report, page 28), which suggests both the possibility of strain differences and the importance of a better understanding of why the same kind of plant reacts differently in slightly different sites.

A comparison of utilization for the years 1951 through 1954 reveals significant differences in amounts of forage removed in the spring. Since the sheep had free access to all species and the amount of forage available during the grazing period was seldom a limiting factor, the amounts removed are considered indicative of relative palatability. Table 7 presents the amounts of forage utilized in the spring by sheep, and the least significant differences for these figures at the 95- and 99-percent levels (t.05 and t.01, respectively).

The differences in palatability between species are not all significant even at the 95-percent level. Significantly more herbage was removed from intermediate wheatgrass than from any other species except pubescent wheatgrass, and more from pubescent wheatgrass than from any of the others except intermediate and the crested wheatgrasses. Significantly more forage was removed from Fairway and standard crested wheatgrass than from tall, bluestem, thickspike, or bluebunch wheatgrass. As a matter of fact, all the introduced species, with the exception of tall wheatgrass, were grazed significantly heavier than the native wheatgrasses. At the Vigilante Experimental Range a similar study also shows that introduced grasses are more palatable than native grasses to cattle. (Schmautz, Jack E. Grass--cafeteria style in southwestern Montana. Research Note 12, 4 pp., 1954.)

Detailed utilization determinations were not made after fall grazing, but general observations indicated a conspicuous change in preference rating of Russian wildrye. In spring this species was only moderately palatable compared with the other species, but in fall it was generally preferred by the sheep.

Changes in Vegetation under Grazing

Benmore, Utah

This is the seventh consecutive year in which 12 grazing treatments have been applied to the 24 100-acre pastures at Benmore. A survey of the vegetation in 1954 showed some interesting differences developing in crested wheatgrass among the three intensities of grazing (table 8).

Table 8.--Response of crested wheatgrass at Benmore to three intensities of spring grazing

Intensity	Plants per 10 sq. ft.		Basal area of crested wheatgrass, percent	"Wolf" plants per 100 sq. ft.
	Total	Small 1/		
Light	18.4	0.89	0.14	3.6
Moderate	18.6	.73	.12	1.8
Heavy	15.4	.57	.09	.1

1/ Plants of less than 1 inch crown diameter

That fewest grass plants are found in the heavily grazed pastures reflects the fact, to some extent, that fewest plants were there at the outset of the experiment. But grass plants have not been increasing in number so rapidly on the heavily grazed pastures as on the others. Since 1951 the increase has amounted to 9.3 percent in the lightly, 5.3 percent in the moderately, and only 0.4 percent in the heavily grazed pastures. Small, presumably young plants were materially more numerous in the lightly than in the heavily grazed pastures in 1954.

The proportions of the ground surface occupied by the bases of living shoots (basal area) show a similar differential. An important contributing factor here is the difference in numbers of plants with dead centers: 24 percent in the lightly, 30 percent in the moderately, and 43 percent in the heavily grazed pastures. Basal area, like numbers of plants, was lowest in the heavily grazed pastures at the beginning of the study. Since 1951 basal area has increased 4.9 and 2.5 percent in the lightly and moderately grazed pastures, respectively, but only 1.4 percent in the heavily grazed pastures.

The numbers of "wolf" plants (ungrazed plants in which old growth accumulates) have decreased in both lightly and moderately grazed pastures during the past 2 years, principally because of poorer-than-average growth conditions. The numbers of these plants fluctuate from year to year, depending upon the amount of forage produced, but the ratio between intensities remains pretty much the same. "Wolf" plants in heavily grazed pastures are found only where protected by brush.

Rubber rabbitbrush and big sagebrush are increasing in all pastures, and the increase is influenced by intensity of grazing. Table 9 shows the numbers of brush plants in 1954 by intensity of use.

Table 9.--Numbers of brush plants per 100 sq. ft. under three intensities of grazing at Benmore

Intensity	Rubber rabbitbrush		Big sagebrush	
	Total	Small 1/	Total	Small 1/
Light	6.5	3.4	1.8	1.0
Moderate	6.0	2.9	2.7	2.0
Heavy	7.5	4.8	12.1	9.7

1/ Plants less then 4 inches tall

The tendency for both rabbitbrush and sagebrush to be most abundant on the heavily grazed pastures is evident, and the greater abundance of small--presumably young--plants there suggests that the difference will become greater as the years pass. Since 1952 numbers of the larger rabbitbrush plants have increased on all pastures--1.1 percent on the lightly, 24.0 percent on the moderately, and 13.3 percent on the heavily grazed pastures. For sagebrush the corresponding increases have been 27.8, 63.7, and 83.6 percent.

Ruby Valley, Nevada

In 1944 a cooperative agreement was developed between private ranchers, Bureau of Land Management, Humboldt National Forest, and Intermountain Forest and Range Experiment Station whereby 825 acres near Arthur in northeastern Nevada were cleared of big sagebrush, fenced, and seeded to crested wheatgrass. For the past 8 years approximately 400 head of cattle have entered the area on the date when, otherwise, they would have entered the Humboldt National Forest, usually around May 20. At this time crested wheatgrass has made most of its growth. The animals remain about 3 weeks. This area has furnished an equivalent of 272 animal-months' grazing each spring--or 1 animal month on each 3 acres.

This area was estimated to provide only 15 to 20 animal-months' grazing prior to treatment, so that grazing capacity has been increased some 15 to 20 times by eradicating brush and seeding to crested wheatgrass. Had adequate water been available, permitting better distribution of cattle, it is estimated that an additional 50 to 60 animal-months' grazing could have been obtained each spring without damage to the grass. This study area has provided an effective demonstration of how an almost worthless tract could be made productive, lessening grazing pressure on higher watershed lands.

Following seeding, cross fences were built, dividing the 2½-mile-long area into 3 pastures of 250, 400, and 175 acres, from north to south, respectively. A plan to graze each pasture at a different intensity was abandoned when water shortages developed and it was necessary to leave gates open between pastures. However, a differential in use developed naturally among the 3 pastures as a result of differences in availability of water. Over the years the south pasture has been grazed most heavily and the north pasture most lightly. There has been a tendency, also, for the western ends of all pastures to be grazed more heavily than other parts.

A survey of the vegetation was made in 1954 in cooperation with Mr. Alvin T. Bleak, formerly of this Station and now with the ARS in Reno. In this survey, effects of the different intensities of use were reflected in the vigor of crested wheatgrass, as shown by differences in numbers of plants with dead centers. In the south pasture 35 percent, in the middle pasture 29 percent, and in the north pasture 23 percent of the crested wheatgrass plants had dead centers. Evidence of the difference in use is given by the numbers of "wolf" plants. These average 4.9 per 100 square feet in the south pasture, 7.9 in the middle, and 12.9 in the north.

Trends in sagebrush were determined by counting annual growth rings and dividing the bushes into age classes accordingly. In table 10 the results are shown, together with those from counts of old plants and seedlings prior to treatment and in 1947.

Table 10.--Numbers of big sagebrush per 100 sq. ft. on Ruby Valley pastures

Age of plants, years	Prior to treatment	1947	1954
Over 10	19.1	3.9	1.3
9 - 10	--	--	4.7
3 - 8	--	--	.1
Less than 3	71.0	6.9	1.5
Total	--	--	7.6

The old plants were reduced about 80 percent by eradication, and were further reduced between 1947 and 1954 to 1.3 per 100 sq. ft. Presumably most of the seedlings present in the pretreatment count were destroyed: most of the 6.9 plants per 100 sq. ft. reported in 1947 probably came in on the disturbed ground. The survivors of this generation in 1954 are found in the 4.7 plants per 100 sq. ft. in the 9- to 10-year age class. The 1.5 plants per 100 sq. ft. which were less than 3 years old in 1954 suggest that sagebrush is increasing. Significantly, these small plants were found almost entirely in the western ends of the south and middle pastures where grazing use has been heaviest.

DEER WINTER RANGE REVEGETATION

At the termination of our 5-year cooperative agreement with the Idaho State Fish and Game Department to investigate possibilities of improving depleted big-game winter ranges by artificial revegetation, a new agreement was drawn up under which the browse revegetation studies will be expanded and intensified. A qualified assistant has been hired by the State of Idaho and assigned to work full time at the Boise Research Center on this cooperative research. The State will also furnish certain temporary help that may be needed on the project. The new agreement, therefore, makes available to the program about twice the personnel formerly working on it.

The major portion of the program for the next 3 years will be devoted to learning more about planting techniques for bitterbrush, proper depths for seeding on different slope aspects, the most important causes of mortality in the early seedling stage, and how to cope with these causes as well as harmful effects of rodents and game on establishment, growth, and survival of artificially planted bitterbrush.

Experimental plantings of nursery-grown bitterbrush will be made on the game winter range to develop a sound technique for this revegetation method. Doubtless browse restoration by planting of nursery stock is more costly initially than direct seeding, but if an effective method insuring a high degree of survival can be perfected, it may be the more economical.

While the revegetation studies are in progress, established stands of bitterbrush, natural and artificial, will be observed to get a better understanding of the species, its reproduction and growth, and its relations with associated species and site factors. Such information will guide planting programs, making possible their sound planning, from selection of site to type of management required to maintain the plantations at maximum productivity.

The search for other suitable browse species will be continued. As propagative material becomes available, these species will be

tested in adaptability plots on the winter range. Among these, as among species already considered potentially useful, some may be difficult of establishment because of indifference to ordinary methods of breaking seed dormancy. If such species should be desirable for revegetation, an attempt will be made to learn the required pre-treatment for enhancing germination.

Progress has been made in developing methods of eradicating competing vegetation in order to plant browse successfully in annual types. There are game winter ranges lacking browse that are of perennial type, however, on which very little work has been done. To restore browse species on these sites we need to know the amount of cover reduction necessary and methods of attaining that reduction. Accordingly an extension of browse-seeding research is being made to these perennial types.

The territory now served by the Intermountain Station embraces all or part of four major river drainage basins. West of the Continental Divide in Montana, Idaho, Wyoming, and eastern Washington are the numerous tributaries of the Columbia River whose waters provide a tremendous potential for hydroelectric power in a rapidly growing Inland Empire. East of the Continental Divide in Montana are the headwaters of the great Missouri River which deliver water to the agricultural Plains States. To the southeast and south in Wyoming, Utah, and Nevada are the Green, Fremont, Paria, Kanab, and Virgin tributaries of the deeply entrenched Colorado River. In Utah and Nevada also are the extensive arid valleys of the Great Basin into which flow many small but vitally important streams from surrounding mountains and plateaus.

In all four major drainage basins there are serious problems of sedimentation, floods, and short water supplies. These water problems have arisen in part from natural causes. It is entirely normal for streams to carry some sediment, to reach flood stage from time to time following unusually deep snows or heavy rains, and to reach low stages of flow during prolonged drought. But these problems of too little, too much, and too muddy water can not be blamed entirely to natural causes, for man's occupancy and use of the land has aggravated them.

Occupancy and development of downstream areas has been an important contributing factor. The choice locations for cities, farms, factories, and for transportation and communication, have been on the valley flood plains of perennial streams. These locations are precisely where recurring damage from floods and sedimentation is inevitable. Even where developments were extended to more elevated and remote terraces and benches, water problems followed. In some places, developments exceeded the available water supply. Where dams, reservoirs, and canals were built to conserve and deliver water, their very locations across channels and arroyos made them vulnerable to damage by floods and sedimentation.

Added to these downstream aggravations has been unwise use of the watershed lands. Wild fires have bared vast areas of forest and rangelands over the years and are a continuing menace. The range forage cover has been depleted by overgrazing on high-elevation summer range, on foothill spring-fall range, and on low-elevation winter range. Logging operations have thinned the forest cover and carved roads and skidways up and down steep slopes. Highways, mining operations, smelter fumes, and other construction work have added to plant cover depletion and to baring and compaction of soil.

These disturbances on the watershed lands have lessened their stability and their capacity to control runoff. Accelerated soil

erosion has decreased the fertility and productivity of the land. Depletion of the natural plant cover has probably affected the annual and seasonal yields of water in local areas, though the magnitude of these changes are not as yet very well known. It is known definitely, however, that thinning the plant cover on watershed slopes in some areas has stepped up flood peaks as much as a hundredfold and has increased the sediment load of streams 1,000 times or more above normal. These are ruinous changes in a territory where usable water and supplies of wood and forage are indispensable.

Correction of present unsatisfactory watershed conditions and prevention of further deterioration must start on the land where rains fall and snows melt. More and bigger dams, though needed in many places, will not keep soil productive and in place on watershed slopes, nor will they affect the runoff behavior of the lands. The problem is to determine where, when, and how much the timber and forage resources can be utilized without accelerating erosion, increasing floods, and stepping up the sediment load of streams, while maintaining maximum yields of water.

These objectives pose many difficult technical problems. For one thing, the Station territory embraces a wide variety of physiographic and climatic conditions. Within each of the four major river drainage basins there are mountains receiving 25 to 65 inches of precipitation per year, foothill and benchlands receiving 15 to 25 inches, and valleys and plains where annual precipitation averages 5 to 15 inches. Within these broad climatic zones are variations in topography, soil, plant cover, and land use practices, each of which has a bearing on the stability and hydrology of the land.

Vegetation, whether in the form of trees, shrubs, or herbs, exerts influences in two directions, hydrologically. Soil stability and control of flood flows tend to increase with amount of vegetation and litter, yet plants both dissipate and use water and thus diminish the amount of rain and snow that can become available as streamflow. Thus it is not hydrologically rational for watershed management to provide maximum soil stability and flood control and maximum water yields from the same land area at the same time. There must be a compromise between these objectives, and in this western area where wild land productivity and the longevity of water storage reservoirs are vital, the choice is clear. That choice lies in the direction of finding the plant cover that will protect the soil and minimize flood discharges while utilizing and dissipating the least water.

During the past year further progress was made in the search for useful guides for the management of the watershed lands in the Station territory. Some of these efforts were focused on soil stability, some on controlling runoff, and some on water conservation.

SOIL STABILITY ON FOREST LANDS

Rapidly increasing demands for sawtimber and salvage operation in bug-killed spruce have extended logging operations into increasingly remote and steep forest lands. Evidence of accelerated erosion points directly to the need for more reliable methods and standards for controlling runoff and maintaining the stability of haul roads and skid trails. This problem is especially acute on the loose granitic soils of Idaho.

In the first phase of this effort observations were made on five timber sale areas in the Boise National Forest. In this study, some 289 groups of observations were made on haul roads and 71 skid trail situations.

Observations on haul roads showed that erosion increased with increase in slope gradient, but in varying degree, depending upon their location. Gully erosion did not occur on ridge locations until road gradients exceeded 14 percent. On hillsides, gully erosion occurred where gradients exceeded 9 percent, and in valley bottoms they occurred where gradients exceeded 5 percent. Length of slope on which runoff accumulates also appeared to be a critical variable. The maximum spacings of cross ditches which appeared to be effective for preventing rill and gully erosion on different gradients were as follows:

Road gradient Percent	Cross ditch spacing Feet
5 or less	100
5 - 9	75
10 - 14	50
14 - 20	25

Observations on skid trails indicated that rill and gully erosion can probably be controlled by installing slash gully plugs, log water bars, or cross ditches, at the following spacings:

Skid trail gradient Percent	Control structure spacing Feet
10 - 20	60
20 - 40	30
40 - 60	20

The above standards are suggested as tentative guides for haul roads and skid trails in ponderosa pine forests having soil derived from coarse granite.

The findings of this observational study were used as a basis for initiating a more comprehensive test of erosion-control methods on haul roads and skid trails in ponderosa pine lands. In this study, provision has been made for evaluating the erosion-control effects of road gradients, spacing of cross ditches, and grass seedings. On skid trails, the study will test the effectiveness of water bars and scattered slash, as well as spacing of these controls, effects of gradients and of location of skid trails with respect to ridges, bottoms, and side slopes.

This study was undertaken in cooperation with the Boise and the Payette National Forests on four different ponderosa pine habitats. On the Boise National Forest, one study area is situated near the upper elevational limits of ponderosa pine (Beaver Creek) and one near the lower and drier limits (Grape Mountain). On the Payette National Forest, one area is situated on fine-textured granitic soil (Salmon River South Fork) and one on clay soil derived from basalt (Little Weiser River). All installations were completed last year.

All phases of a long-term study of the effects of logging disturbance and methods of cutting on sediment production from virgin ponderosa pine lands at the Boise Basin Experimental Forest were completed last year. The study is being made on 20 compartments of about 100 acres each in cooperation with the Division of Forest Management Research. Sixteen of the compartments have been cut and logged and four have been kept in virgin condition. Erosion surveys have been made on all compartments prior to cutting and logging for comparison with the followup surveys. Cross section measurements have been made on representative segments of logging roads, skid trails, and drainage bottoms. Dams and sediment traps have been installed and profiled for storage capacity on representative subbasins in each of the 20 compartments. The stage is thus set for beginning measurements in 1955 of erosion and sediment production as affected by different methods of harvest cutting and logging.

SOIL STABILITY ON RANGELANDS

How much plant and litter cover is necessary to maintain the stability of soil and minimize summer storm runoff is one of the major questions involved in management of range-watershed lands. Closely related is the problem of restoring an adequate cover on lands in unsatisfactory condition. Efforts to find answers to both questions have been concentrated on the subalpine herbaceous summer range at the Great Basin Research Center in central Utah; on high-elevation aspen-herbaceous range at the Wasatch Research Center in northern Utah; and on foothill, spring-fall range at the Boise Research Center in southwestern Idaho.

Previous study at all three locations indicated that both soil losses and summer storm runoff increased at accelerated rates under

the impact of high-intensity rains when progressively more than about one-third of the soil was bared. Further evidence of the ground cover-rainfall intensity relation to erosion and runoff was obtained last year at both the Great Basin and Wasatch study areas.

At the Great Basin, 32 summer rains fell on the A and B experimental watersheds but none of these storms caused runoff or soil loss from either watershed. Effective control of these storms is attributable in part to the small volume and low intensity of rainfall, but more particularly to the amount of vegetation now on the two areas. More than half the ground surface on Area A now has a plant cover as compared to less than a 20-percent cover in earlier years. Area B has a similar plant cover, whereas in 1951 and 1952 its plant cover was only about 20 percent. The quick recovery of Area B was accomplished by plowing and seeding the area to grass in the fall of 1952.

The records show that whereas neither Area A nor B produced runoff or sediment in 1954, equally small and low-intensity rains caused runoff from Area B in 1951 and 1952 when it was in depleted condition (table 11). That storm runoff can be caused by less than 0.20 inch of rain indicates the vulnerability of range-watershed lands in this area.

Table 11.--Comparative runoff behavior of Area B during three of the largest summer rains in 1954 and during comparable storms in 1951 and 1952

1954		1951 and 1952	
Rainfall	Runoff	Rainfall	Runoff
Inches	Cu.ft./A.	Inches	Cu.ft./A.
0.19	0	0.20	132
.17	0	.15	24
.14	0	.13	46

At the Wasatch Research Center, 25 rains fell on the range plots in the head of Parrish Creek during the past summer. Total rainfall amounted to 7.51 inches. The volume of individual rains varied from 0.02 to 1.17 inches and maximum 5-minute rates varied from 0.12 to 2.28 inches per hour. Eight rains produced runoff and caused soil erosion, but the only areas that lost any measurable quantity of soil or produced any significant amounts of runoff were those that have been kept denuded of vegetation (table 12). As in previous years with even greater intensities of rainfall, the areas having 60 percent or more of the ground covered by plants and litter have lost no soil and have permitted less than 5 percent of the rainfall to run off as overland flow.

Table 12.- Average amounts of soil eroded and rainfall runoff under four range conditions at Parrish Plots, summer of 1954

No. of plots	Plant cover type	Ground cover	Soil eroded	Rainfall runoff	
		Percent	Cu.ft./A.	Cu.ft./A.	Percent
3	Bare	0	122	4,379	21
3	Herbaceous	60	0	441	2
6	Snowberry-sage	70	T	465	3
4	Aspen-herbaceous	88	0	369	2

At the Boise Research Center a battery of four runoff and sediment measuring plots was installed in the foothill zone of the Boise River watershed in cooperation with the Boise National Forest. These plots will be used to determine the effectiveness of artificial seeding and exclusion of grazing for stabilizing the highly erosive granitic soils of that area.

FLOOD CONTROL

Two radically different types of floods occur in the Station territory. One is the snowmelt flood which usually occurs in spring or early summer. These are generated from the prolonged melting of deep accumulations of snow on the more elevated watershed lands. Because of the relatively slow release of water from the snowpack and because very little runoff occurs as overland flow, these flood discharges never attain very high peaks, though strong flows may be sustained for weeks at a time. The other type is the flood from brief torrential summer rains. These can be generated by rains of less than 1 inch when the rain falls faster than it can be absorbed by the soil. Notwithstanding the small volume of rain required, these summer floods can discharge in excess of 1,000 cubic feet per second per square mile of watershed drained and can transport tremendous quantities of sediment, including boulders weighing more than 100 tons.

Flood control studies at this Station have been devoted mainly to the summer storm type and much of that effort has centered on the Davis County Experimental Watershed in northern Utah. Analysis of the behavior of three of the subwatersheds in that area covering the period 1936 to 1953, inclusive, show how restoration of plant cover on headwater flood-source areas has affected annual and seasonal water yields, as well as stormflow discharges.

The three watersheds have undergone different treatments and have different flood histories. Centerville watershed, the southernmost, has never been abused and has not produced any mud-rock floods since long before settlement. Parrish watershed, immediately adjacent to Centerville, produced four major mud-rock floods in 1930 when about 10 percent of the headwater lands was in depleted condition. The flood-source areas were contour trenched and seeded to grass in 1934 and 1935. It has not flooded since 1930. Halfway watershed, some 3 miles north of Parrish, was in equally depleted condition in 1930. Very little improvement work was done in this watershed and the headwater areas are still depleted. This watershed produced mud-rock floods in 1923, 1930, 1936, and 1947. The last occurred during a rain of only 0.79 inch in which the maximum rate of rainfall for 5 minutes was 4.92 inches per hour.

Since 1936, Centerville and Parrish watersheds have each been subjected to six summer rains of equal or greater volume and rate than the rain which caused the 1947 flood in Halfway Creek, but neither has produced any semblance of a flood. Their streamflow records show that the volume of storm runoff was only about 0.01 areal inch, or about 1 percent of the rainfall. Because there was practically no evidence of overland flow on either of the watersheds, it is apparent that the minor and short-lived rise in streamflow was due almost entirely to the rain that fell in each creek channel.

Further analyses were made of the 17-year streamflow records from Parrish Creek to determine whether the watershed improvement work for flood prevention had affected annual and seasonal water yields. Centerville Creek was used as a comparison because there has been little change in watershed conditions on that area during the period of record.

Annual runoff for the period of record has averaged 12.74 areal inches from Parrish watershed and 13.17 inches from Centerville. Similar fluctuations in each watershed occurred from year to year by reason of annual fluctuations of precipitation. Over the period of study, annual yields in both watersheds have a slight upward trend, reflecting greater than average precipitation in recent years. However, Parrish watershed yielded about 1 inch more runoff annually than Centerville during the first 5 years of record, whereas in recent years Centerville has been yielding about 1 inch more than Parrish.

Parrish Creek runoff during the fall, winter, and late summer months has not differed significantly from that of Centerville. Parrish Creek streamflow has diminished during the snowmelt months of March, April, and May, on the order of 0.36 to 1.25 inches per month. Flow in June, however, has been slightly increased.

These analyses show that restoration of plant cover on depleted headwaters of the Parrish watershed accomplished more than prevention of devastating summer storm mud-rock floods. It also lessened the

hazard of spring snowmelt floods at a time of year when water supplies are generally ample, and it strengthened June streamflow without significantly diminishing water yields in late summer.

An investigation of soil moisture on representative portions of the headwater lands in Parrish watershed at the end of the growing season last fall suggested why spring runoff has been lessened. On areas that have purposely been kept denuded, the soil mantle to a depth of 6 feet contained about 3 inches more water than areas having an annual weed cover, and about 8 inches more than those having a two-story aspen-herbaceous plant cover. When these depletion moisture contents are compared with the capacity of the soils to hold water against the force of gravity, they show that less than 7 inches of winter precipitation will recharge the soil on the bare areas, whereas from 10 to 12 inches of water will be required to recharge the plant covered areas (table 13). Further investigations of these moisture recharge relations are planned for 1955.

Table 13.--Recharge requirements (water storage deficits) of 6-foot soil mantles on Parrish watershed headwater areas at end of growing season, 1954

Plant cover conditions	Field moisture capacity	Depletion moisture content	Recharge requirement
	Inches	Inches	Inches
Bare soil	20.56	13.68	6.88
Annual weed	20.59	10.44	10.15
Perennial grass-weed	1/ 20.51	8.43	12.08
Sagebrush-herbs	18.00	6.39	11.61
Aspen-herbaceous	16.19	5.46	10.73

1/ Estimated value

UPSTREAM WATER CONSERVATION

Watershed management on rangelands must strive for plant cover and soil conditions that will minimize soil losses and storm runoff, and at the same time produce maximum forage yields at the least cost of water. Last fall further information was obtained at the Great Basin Research Center on the relative efficiency with which several kinds of summer range plants utilize moisture for forage production and the water storage deficits they create in the soil mantle by the end of the growing season. The study was made on a high-elevation summer range where winter snows always provide more than enough water to saturate the soil mantle each spring. The snow water that is surplus to the soil-moisture storage deficit in the fall is the principal source of water for perennial streamflow next year. The moisture

that is retained in the soil mantle following disappearance of snow plus summer rainfall, is available for plant growth.

In 1952 and 1954, comparable information was obtained on three types of range cover, smooth bromegrass, Kentucky bluegrass, and mixed weeds. During the growing season of 1952 precipitation totalled 3.47 inches, and in 1954 it was 5.00 inches.

On each of the three plant cover type areas, soil moisture deficits and forage production were nearly the same in the 2 years of record notwithstanding about 1½ inches more summer rainfall and evapo-transpiration loss in 1954 (table 14). As in 1952, smooth bromegrass

Table 14.--Soil-moisture deficits, evapo-transpiration losses, and forage production on high-elevation summer range, Great Basin Research Center, 1952 and 1954

Plant cover types	Soil-moisture deficit		Growing-season evapo-transpiration		Forage production	
	1952	1954	1952	1954	1952	1954
	Inches		Inches		Lbs./A.	
Smooth bromegrass	7.86	7.81	11.33	12.81	4,181	4,138
Kentucky bluegrass	6.31	6.98	9.78	11.98	2,425	3,000
Mixed weeds	5.49	5.24	8.96	10.24	700	700

produced most forage per inch of water available for growth but it also dried the mantle most. Kentucky bluegrass areas were less efficient in utilizing water for forage production, but left the mantle in condition to yield about 1 inch more water next year. The areas with thin weed cover left the mantle in condition to yield from 1 to 2½ inches more water in the following year than the grass-covered areas but, on the other hand, they produced only one-sixth to one-fourth as much forage. Moreover, numerous tests have shown that thin weed stands are very unsatisfactory for maintaining soil stability and for controlling destructive flood runoff.

The differences exhibited by these three types of cover, though based on limited and exploratory data, indicate how and to what extent alterations in summer range plant cover can affect both forage production and water yields. They substantiate the well known facts that plants require water for growth and that some plants are more efficient in their use of water than others. It is planned to continue studies in this field.

During the past summer the installation phase of a soil-moisture study was completed at the Wasatch Research Center. This study involves 16 plots, each of which has been planted to a mixture of summer range grasses. Each plot is equipped with Colman fibreglass soil-moisture

units to depths of 6 feet, a surface runoff subplot, and precipitation gages. Following establishment of the grass stand, it is planned to use this installation to determine the effects of seasonal grazing on productivity and hydrologic behavior of the study areas.

SOIL STRENGTH SURVEYS

During the past year several studies were made for the Corps of Engineers on the trafficability of soils. One phase of this effort was devoted to development of methods for predicting soil-moisture contents. This involved study of rates at which soils gained and lost moisture on a variety of sites. Prediction equations were developed for three soil sites in the vicinity of Miles City, Montana, and for five sites near Rockford, Washington. The latter study will be completed early in 1955.

In a second phase of work, a soil-moisture-strength survey was initiated last summer out of the Wasatch Research Center. This survey will obtain information on soil strength characteristics at 148 sites in Utah, Nevada, and southern Idaho. Data at these sites will also be used to test the accuracy of soil-moisture prediction methods. This study is scheduled for completion in 1955.

FOREST INSECT RESEARCH

By the reorganization of the Department of Agriculture in November 1953 the Intermountain Station acquired the Division of Forest Insect Research, formerly under the Bureau of Entomology and Plant Quarantine of the Agricultural Research Administration. The Division maintains entomologists at Coeur d'Alene, Idaho and Ogden, Utah working on forest insect problems of the Intermountain region. The Coeur d'Alene laboratory has been established in the northern area for many years while the Ogden unit has been in existence since 1949. With the consolidation of the Intermountain and Northern Rocky Mountain Stations, headquarters for the forest insect studies have been established at Ogden. It is planned to move the personnel at Coeur d'Alene to Missoula in the near future.

The work of the Division falls into three rather distinct but related fields--research into the biology and ecology of forest insects as a basis for the development of satisfactory and economical methods of control; surveys to detect and appraise infestations to determine entomological soundness of control possibilities; and technical advice to all land managers in carrying out control procedures. Active cooperation with all land managing agencies, Federal, state, and private, is an essential part of all phases of the program.

RESEARCH

Forest insect problems in the Intermountain region are numerous and diverse. The region, extending as it does from Canada to Arizona and California, includes a wide variety of climatic conditions, forest types, and forest insects. It might be said that the Intermountain region has all the insect troubles of other western forest areas plus some peculiar unto itself. The primary insects include the tree-killing bark beetles such as Dendroctonus spp. and defoliators such as the spruce budworm, pine butterfly, tussock moth, and needle miners. There are, however, a number of insects of lesser importance that do cause considerable damage and should be the subject of future research. During 1954, with the exception of one cooperative study with the Division of Timber Management Research at the Boise Basin Experimental Forest, all research reported herein was conducted from the Coeur d'Alene laboratory. The Boise Basin study was conducted from the Ogden laboratory.

Engelmann Spruce Beetle

With the development of a serious and extensive outbreak of Engelmann spruce beetle in Montana and Idaho in 1952 a program of research was started in order to determine facts that would aid in control of the infestation. This work was continued in 1954. Facts developed

reveal that there are differences in the behavior of the beetles from that noted in the Colorado outbreak. The number of attacks per square foot of bark surface was less and the variation in seasonal temperatures seemed to vary the percentage of 1- and 2-year broods within areas more strongly than in Colorado. The facts have a bearing on control plans. While trap trees for control of bark beetles have been tried with a number of species, most tests have not proved effective. Research with trap logs in the Montana outbreak indicates that trapping spruce beetles by felling trees may have distinct possibilities in control programs. Data are being accumulated on the natural enemies of the spruce beetle.

Risk Rating of Ponderosa Pine

In the eastside ponderosa pine stands of California and Oregon it is possible to classify individual pines by a combination of visible characters and to assign them a rating of risk as to degree of susceptibility to beetle attack. Removal of high-risk trees has proved an excellent method of preventing losses from beetle attack. In 1950 an experiment was started in western Montana to test the effectiveness of this system of rating under conditions in that area. Facts have been developed on stand structures, distribution and characteristics of high-risk trees, and rate of beetle-caused pine mortality. The study has already shown some positive relations between the occurrence of high-risk tree volumes and certain stand characteristics such as age, growth rates, site quality, and previous beetle-caused mortality, as well as a preference by the beetles for trees classified in the high-risk category.

Selective Logging to Control Pine Beetles

Following the classification of ponderosa pine stands by the risk-rating system, selective logging is done to remove the high-risk element of the stand. This is commonly termed sanitation-salvage cutting. In 1950 several hundred acres of pine were logged in Montana on this basis. By this method attempts are being made to "beetle proof" the residual stands during the 30-year cutting cycle immediately following the sanitation-salvage cut. The 1954 survey indicated that pine mortality was appreciably less during 1953 and 1954 on the treated areas than on adjacent uncut areas.

Douglas-fir Beetle

During 1954 it was decided to establish a long-term study of the Douglas-fir beetle in the Intermountain area. As a first step a problem analysis is under way, and considerable factual information has been accumulated such as resource statistics, economic considerations in the utilization of Douglas-fir forest products, and the influence of beetle infestations on both the resource and the economy of the timber species. It was possible to observe and discuss the

progress of studies by Canadian entomologists which will aid in formulating plans for the study in this region.

Spruce Budworm

Research on certain phases of a study of spruce budworm has been under way for the past few years in Montana and Idaho. Because of the importance of the species in the Intermountain area, and because of interrelations between spruce budworm and Douglas-fir beetle, a long-term study of budworm is being planned. Trees heavily defoliated by budworm are more susceptible to attack by the bark beetle than non-defoliated trees. Plots have been established in the northern Rocky Mountains in order to study the biology and ecology of the species. Additional data were accumulated in 1954 to establish a correlation between the overwintering budworm populations and subsequent host tree defoliation. If completely satisfactory methods of measurement are developed from this study, it will be possible to forecast where heavy defoliation will occur.

Improvement of Insect Survey Methods

An important phase of the research program is the improvement of ground and aerial methods of forest insect surveys. At the Coeur d'Alene laboratory some studies were initiated in 1954. By field test an improved 2-inch scale compartment map proved very satisfactory for recording drainage and cultural features, timber type boundaries, sample strip lines, and locations of infested trees on sample strips. These maps were constructed from aerial photo strip maps obtained from the Division of Forest Economics Research. An improved method in the identification of external characteristics of beetle-attacked trees was developed which has value in dating the year of kill of trees attacked by Engelmann spruce beetles, and in properly identifying trees still containing active infestations of Douglas-fir beetle. The method will prove helpful in timber marking to remove infested trees.

Cooperative Study - Boise Basin

A study has been started on the Boise Basin Experimental Forest in cooperation with the Division of Forest Management Research. It is planned to study insect conditions and activities over a period of years in reserve stands of ponderosa pine following different methods of logging on a selective cutting basis. Selective logging in this area has been followed by excessive losses in the residual stand. The long-term study may reveal the factors causing losses from insects in these stands.

INSECT SURVEYS

The Division has the responsibility for detection and appraisal surveys under provisions of the Forest Pest Control Act. One problem

is to develop cooperative detection surveys to discover epidemic tendencies in populations of forest insects, and another is to appraise the seriousness of the infestations and report to land managers, regardless of land ownership. The total acreage of forest lands, commercial and noncommercial, in the area covered by the Intermountain Station approximates 88 million acres. Suitable detection reporting over such an acreage can only result from a highly developed cooperative system including all individuals interested in forest protection. Appraisal surveys are highly technical and demand the best analysis of each situation by trained entomologists.

In the southern part of the Intermountain region under the jurisdiction of the Ogden laboratory staff, survey needs in 1954 were numerous. One was a serious pine butterfly infestation on the Boise National Forest. It was necessary to conduct surveys prior to the aerial spray operation, and afterward a survey was made to determine the effectiveness of control and locate areas that might need additional treatment. The continuing bark beetle control project on the Dixie National Forest and Bryce Canyon National Park necessitated several surveys during the season. In addition, areas where cooperators reported unusual insect activity were examined to determine the status of infestations, and reports were issued.

Within the area covered by the Coeur d'Alene laboratory the major survey effort was made to determine the status of the Engelmann spruce beetle, mountain pine beetle in lodgepole pine, and spruce budworm in Douglas-fir and true fir. Cooperative aid in detection revealed a number of less important infestations that were examined by the entomologists. Aerial observations proved highly successful in revealing general conditions and also aided in locating developing centers that could be checked by ground surveys.

TECHNICAL ADVICE ON CONTROL

The Division has responsibility for technical advice to all land managers on insect control projects. Station technical personnel assist in planning control projects, recommend methods, materials, and timing, train project personnel in control procedures, inspect operations to see that effective work is being done, and analyze results. The work load varies greatly and during periods of severe outbreak conditions may overtax available technical personnel, requiring help from detailers.

The Ogden laboratory had two important control projects in its area during 1954 on which it furnished technical assistance to the operating agencies. Entomologists assisted in the planning for control of the pine butterfly aerial spray project on the Boise National Forest, gave on-the-ground technical advice to insure proper timing and application of aerial sprays, and determined results of the operation. The same type of technical service was furnished to National

Forest Administration and the National Park Service of the Department of the Interior in connection with the cooperative project against the Black Hills beetle on the Dixie National Forest and Bryce Canyon National Park.

The Coeur d'Alene laboratory furnished technical assistance to land managers in the current large-scale project to control the outbreak of Engelmann spruce beetle in the northern Rocky Mountain region where more than 2 billion feet of spruce has been killed since 1952. Control is being attempted primarily by logging with some use of trap logs in areas where logging is scheduled but not yet started. A large share of the technical assistance effort in 1954 consisted of correlating the biological developments of the insect with the timing of treatment of the trap logs.

FOREST DISEASE RESEARCH

In common with other forested sections of the United States, the Intermountain area has important forest disease problems. In eastern Washington. northern Idaho, and western Montana, pole blight of western white pine is certainly the most serious at present. Found extensively throughout most of the range of this species in the northern Rocky Mountains, it is particularly disturbing because it attacks and kills young pole-size stands which are just approaching their period of most valuable growth. Neither its cause nor its means of spread are known.

Blister rust of western white pine is still very serious. The Division of Blister Rust Control in Region One of the Forest Service is working full time on it. Close cooperation exists between this Division and Station pathologists, entomologists, and silviculturists assigned to the Inland Empire Research Center, Missoula Research Center, and Missoula Insect Laboratory.

Other important disease problems of the northern forests include:

Dwarfmistletoe. A serious loss factor in western larch, Douglas-fir, and lodgepole pine; somewhat less serious in ponderosa pine.

Heart rots. Infect grand fir and western hemlock at an early age and lead to substantial losses.

Diseases following logging damage. Studies needed here and in estimation of defect to aid forest management.

Root rots. Are causing serious losses to western white pine and Douglas-fir particularly.

Needle casts. Now important on Douglas-fir, ponderosa pine, and western larch.

Pine rusts. Causing defect losses in the so-called inferior species now coming into increasing use.

Deterioration of fire- and insect-killed timber. A serious matter brought into sharp focus by recent Engelmann spruce beetle attacks.

Further south in the Station area, *Elytroderma* needle disease of ponderosa pine is probably most noteworthy, being particularly severe at the present time in parts of central Idaho. Trees become progressively weakened and usually die. Unfortunately, losses have been heaviest in the younger age classes--the trees normally left as a reserve stand in partial cutting operations.

The following disease problems also stand out in the central-southern area:

<u>Dwarfmistletoe</u>. Serious on lodgepole pine, ponderosa pine, and Douglas-fir.

<u>Postlogging mortality in ponderosa pine</u>. A complex situation with insects and other causes tied in with diseases. <u>Fomes annosus</u> (root rot) appears to be the most important disease involved.

<u>Pine rusts</u>. Serious on lodgepole pine and ponderosa pine.

<u>Leaf and twig disease on aspen</u>. Causing widespread damage; kills trees in patches.

<u>Heart and butt rots</u>. Need studies of this important problem in Engelmann spruce and alpine fir, including investigation of external indicators.

In the face of so many critical problems, the small force of disease workers at Intermountain Forest and Range Experiment Station is inadequate indeed. It is essential that planning of research projects be highly selective so that efforts are directed against the diseases of highest priority. In deciding which studies to make first, due regard is paid to existing research facilities, particularly experimental forests, so that maximum help can be obtained from Station silviculturists and entomologists.

All disease research is closely integrated with activities in the same field by other stations and institutions. For example, the University of Idaho and Intermountain Station have for some years worked as partners in studies of pole blight of western white pine. Frequent meetings and free interchange between individual workers in the field keep this cooperation real and up-to-date.

Three pathologists and one soils scientist are presently on the staff of this Station. Two pathologists and the soils scientist are stationed at the Inland Empire Center and are working on the pole blight project. The other pathologist is stationed at Logan, Utah and is concerned primarily with <u>Elytroderma</u> needle disease.

Again in 1955 Forest Disease efforts at the Intermountain Station will be concentrated against pole blight of western white pine and <u>Elytroderma</u> needle disease of ponderosa pine. Observations will be made of other diseases encountered to accumulate a fund of information against the day when it will be possible to investigate these additional disease problems. Some time must be devoted to requests for information on tree diseases from practicing foresters and the general public.

POLE BLIGHT OF WESTERN WHITE PINE

For the first time since investigations of pole blight of western white pine began, the Station was able in 1954 to launch an integrated attack at the phases of the problem being studied by the Forest Service. Forest pathologists, a soils scientist, and silviculturists working side by side provide a team approach to unveil this mysterious malady and point up avenues of effective control. Although considerable time was required at the start for equipment development and construction of a soils-pathology laboratory at the Inland Empire Research Center, progress was made during the season. Major accomplishments are:

1. A study of lesions associated with pole blight of western white pine indicates that growth reduction is a symptom invariably associated with pole blight and suggests that lesion development and crown decline follow growth reduction at extremely variable rates. A report has been prepared and submitted to the Journal of Forestry for publication.

2. Physiological studies of Leptographium sp. have disclosed no different species among isolates of this fungus obtained from pole-blighted white pines. Leptographium sp. has been extensively studied during the past 6 years because it is one of the common fungi obtained in isolation studies of pole blight. Studies of physiological aspects, including nutritional requirements, were carried out on four isolates of this fungus. Although no significant differences in growth requirements were found to exist between the four isolates, general temperature, pH, and vitamin requirements were determined and reported for the first time for members of this genus. The results of this study were submitted in a dissertation to fulfill Ph.D. requirements and will also be submitted for publication in Mycologia.

3. Results from inoculations made with Leptographium sp. show that this fungus, or at least the isolates of this fungus used in the tests, is not the primary cause of pole blight. Final observations made on inoculation plots established in 1949 show that none of the inoculated trees have produced the characteristic symptoms of pole blight to date.

4. Grafts of pole blighted scion material on healthy stock have been successful. The results of grafts made in the spring of 1954 on 6-year-old white pine stock are shown in table 15. Scion material was collected from the upper, middle, and lower crowns of 6 healthy and 14 diseased trees.

Table 15.--Number of grafts made and number living at end of first growing season

Scion condition	Total grafts	Grafts dead	Grafts living: 1954 growth developed	Grafts living: No 1954 growth
Blighted	168	82	27	59
Healthy	62	25	26	11

Successful grafts were obtained using scion material from trees in all stages of disease and from the 3 portions of the crown sampled.

5. The initiation of a coordinate soils-rootlet mortality study marked the beginning of a more concerted effort to determine the cause of the pole blight disease. In healthy and diseased stands of various site classes root samples from three successive 1-foot depths were collected and healthy and dead rootlets tabulated. Intensive soil sampling was done to determine possible relations between soil characteristics and the condition of the root systems in the various stands.

6. Distribution surveys of white pine pole blight along the southern limits of the disease on the St. Joe National Forest indicate that most of the larger diseased areas have been found. No pole blight was found in stands classified as healthy in 1953, but in several instances pole blight was found in what were formerly healthy portions of diseased stands. The established range, the southern limits, and the estimated acreage of the disease remain about the same.

7. Damage appraisal surveys in four pole-blighted stands each on the St. Joe, Kaniksu, and Coeur d'Alene National Forests indicated that from 50 to 80 percent of the white pine poles are either blighted or blight killed.

8. Analysis of records from white pine plots established and thinned prior to the existence of pole blight in the stands shows that an abrupt decrease in diameter and volume growth and an increase in mortality coincided with the appearance of pole blight in the stands.

BLISTER RUST RESISTANCE IN WESTERN WHITE PINE

Mass artificial inoculations of western white pine progenies during 1953-54 to test their resistance to blister rust were highly successful in producing infection. Success of the tree breeding project aimed at producing a rust-resistant white pine depends in part on

satisfactory methods of artificial inoculation which secure heavy and uniform inoculation in order to test the resistance of each progeny to the disease in the minimum time. That the mass inoculation method used in 1953 was successful is demonstrated by the fact that needle spotting resulted on all progenies inoculated. Inoculations were made in the fall of 1954 on 1-0 progenies to be outplanted in 1956 and on 2-0 progenies inoculated in 1953 to be outplanted in 1955. To date, approximately 15,500 plants have been inoculated at least once, over one-half of which will have been inoculated twice prior to outplanting in 1956.

PONDEROSA PINE NEEDLE DISEASE

This native disease has been known for many years to occur throughout most of the range of ponderosa pine. It is not a recent invader of this region; it was reported from the Deadwood area of the Boise National Forest over 40 years ago.

Studies, which were initiated in central Idaho during 1948 on the needle fungus (Elytroderma deformans) were expanded in 1951. The main results of these studies, which have not been previously summarized, are:

1. The greatest intensity of infection on the disease areas occurred in 1950 and 1951.

2. Trees recorded as lightly infected in 1951 are still lightly infected, indicating individual resistance to the pathogen.

3. Mortality has occurred only among those trees that were classified in 1951 as "poor" or "very poor" in vigor because of their severely diseased condition.

4. Losses have been confined almost entirely to the younger age classes. The largest tree killed was 28 inches d.b.h. On 6 plots in heavily infected mature stands 13 or 8.1 percent of the total of 161 trees died between 1951 and 1954, resulting in a volume loss of 6,220 bd. ft., or 4.3 percent of the original volume. Increased losses have been the result of the cumulative effect of repeated annual infection rather than any material spread or increase in severity of the disease.

All evidence indicates environment to be highly important in development of the fungus. There has been no material increase in size of the areas on which the pathogen was observed to be abundant and destructive as early as 1946 or 1947, the years in which it first came to attention as epidemic in Idaho. Severe damage by the disease seems to be confined to (1) the upper altitudinal limits for ponderosa pine on south and west slopes and on ridge tops, where the tree is not

reproducing satisfactorily and intergrades with such species as Douglas-fir, larch, lodgepole pine, alpine fir, and Engelmann spruce; (2) cool basins; and (3) cool ravines.

The behavior of the fungus appears to be no different on the Bitterroot National Forest than elsewhere in the Intermountain area. It was not noted as present or destructive generally, but appeared to be confined to certain areas where environmental conditions evidently are favorable for the pathogen.

Very few young ponderosa pines less than 5 feet in height appear to be susceptible to the fungus.

Field spray tests on Elytroderma deformans and subsequent laboratory studies, indicated that all seven fungicidal materials employed in the experiments were highly effective in preventing spore cast and germination.

All attempts to grow the fungus in culture have been unsuccessful. It is doubtful whether this organism can be grown in culture by any method now in use.

CONSULTATION

Numerous requests for identification and suggestions for control of tree diseases were received the past year. They came from foresters managing public or private forest lands and from persons concerned with damage or loss of yard trees. In all cases available information was provided. Where it could be arranged in connection with travel to and from research projects, the afflicted areas were visited and advice given on the ground.

Consolidation of the old Northern Rocky Mountain and Intermountain Stations brings a fire-research program for the first time to a vast area of the Inland West. The new research territory, encompassing nearly one-sixth of the land area of the United States, contains somewhat less than 100 million acres of forest lands and a vast area of rangelands requiring protection from fire. Today, as when forestry programs first started in this region, fire control and hence fire research is a fundamental element of sound management. There is still plenty of opportunity for pioneering in these ventures. The size and challenge of the fire-research job is shown in table 16.

Table 16.--Forest fires in the Intermountain Station territory

State	Forest area needing first protection	Average annual number of fires[1/]	Average annual area burned[1/]
	M acres		Acres
Montana	25,155	953	29,980
Idaho	29,081	1,555	62,557
Washington (northeastern)	3,857	342	12,986
Wyoming (western)	8,418	173	5,181
Utah	21,375	175	3,316
Nevada	13,844	68	4,951
Total	101,730	3,266	118,971

1/ Basis U. S. Forest Service Annual Fire Reports 1929-1953, Washington and Wyoming figures prorated from state totals.

FOREST-FIRE LABORATORY

During 1954 a forest-fire laboratory was organized at Missoula. The laboratory has a dual function: (1) to perform fire research for the special problems of the forests and ranges of the Inland West, and (2) to carry on basic fire research that may have eventual application in any region. The forest-fire laboratory is organized to provide a task-force approach to the various fire-research problems through concentration of effort at a research center and cooperation with a score of private, state, and Federal agencies. A field arm of the laboratory will be maintained at the Priest River Experimental Forest.

The advance of the fire phase of forestry science is dependent in large measure on fundamental knowledge of two highly important factors--fuels and weather. Each of these factors is being studied at the laboratory in the projects on logging slash, fire-danger rating, and lightning. Applied research is also an important part of the laboratory program. In cooperation with many forestry agencies of this region the laboratory provides research service on fire-weather instruments, fuel-moisture-stick manufacture, fire detection, aerial fire control, fire behavior, prescribed burning, fire-control planning, and statistical analysis of regional fire-control problems.

FIRE-DANGER RATING

New Burning-Index and Fire-Danger Meter

The Model 7 burning-index and fire-danger meter was issued for operational use during the 1954 fire season. The meter is used to evaluate fire weather throughout Regions 1 and 4, by national parks, and by timber protective associations.

A major feature of the new burning-index meter is a seasonal or severity index which aids in interpreting fire-season trends through evaluating ½-inch-stick moisture over a 7-day period. Studies at the Priest River Experimental Forest have shown that seasonal loss or gain of moisture in heavy fuels may be evaluated through measurement of ½-inch-stick moisture. A long period of below par fuel moisture indicates the buildup of possibly dangerous fire conditions if accompanied by other factors contributing to high burning index. Incorporation of this feature in the new burning-index meter eliminates the calendar date factor used on previous meters. The result is a more reliable rate of burning index through spring, summer, and fall.

Other features of the Model 7 meter include greater sensitivity to both very high and very low burning index, a guide for forecasting tomorrow's ratings, and a conversion factor for estimating burning index at some other time and place on mountain slopes. Greater sensitivity to very high and very low burning index is made possible through use of multirange scales of relative humidity, fuel moisture, and wind velocity. This greater sensitivity makes the new meter especially useful in evaluating conditions for slash burning and prescribed use of fire. The predicting features of the meter enable the use of standard fire-weather forecasts for estimating tomorrow's burning index and fire danger. Conversion of burning index from the station where measured to some other point nearby and to some other time up to 8 hours is accomplished by a table which evaluates slope and elevation effects during 3 periods of the day. Burning-index conversions are especially useful in estimating rate of spread on going fires.

Use of the Model 7 meter throughout the Inland West enabled the first widespread operational test to be made of the many new features

in this system of rating burning index and fire danger. Results of the first year's use of the new meter are being carefully evaluated.

Fire-Danger-Rating System

In addition to the use of the new burning index meter, 1954 marked the standardization of many other phases of the fire-danger-rating system in the Intermountain Station territory. All agencies are now using the same forms for recording and reporting fire danger. Fire-danger-rating data from the entire 6-state area of the Station are now sent to the forest-fire laboratory at Missoula. Availability of these data will be an important factor in analyzing each fire season and in performing basic research in fire weather and fire-danger rating. Over 300 fire-danger-rating stations are now included in the program.

1954 marked the 21st year in which an analysis has been made of fire-season severity in the northern Rockies. The analysis shows that 1954 was the easiest fire season in Forest Service Region 1 since the rating system was started, rating only 13 percent of worst probable fire danger. During the period 1934 through 1954 there have been 3 fire seasons rated critical, 12 average, and 6 easy. A critical season has 68 percent or more of worst probable fire danger, an average season 33 to 67 percent, and an easy season 32 percent or less. The last critical fire season occurred in 1940. During the last 14 years there has been a remarkable period of noncritical fire weather in the northern Rockies.

Research in the special problems of fire-danger rating in Forest Service Region 4 was started in 1954. Visits were made to the Payette, Boise, Salmon, Challis, Targhee, and Teton National Forests and the Grand Teton National Park to survey factors associated with the location of mountaintop and valley-bottom fire-danger-rating stations. Both aerial and ground reconnaissance were made of these areas where possible. Fire-danger-rating problems in Utah and Nevada will be studied during 1955.

Large Log Study

At the Priest River field laboratory studies have been under way since 1942 of the moisture content of large logs. A major purpose of this study has been to determine whether or not the moisture content of heavy fuels indicates critical burning conditions. The results of this study of heavy fuels has been a major factor in development of the Model 7 burning-index meter. The normal seasonal trend of large-log moisture contents follows very closely the actual weather behavior. The effect of a dry May, wet June, late August rain, Indian summer, and fall rains can all be found from the moisture-content curve of large logs. The over-all results of this study will be published in 1955.

Fire-Danger-Rating Instruments

The forest-fire laboratory has been assigned responsibility for carrying out a servicewide project in the development of new and improved fire-danger-rating equipment. The scope of the project is broad. It includes such items as portable fire-danger stations, weekly recording and automatic fire-danger stations, small motor-driven fan psychrometers, and electrical resistance-type fuel-moisture scales.

A nationwide survey is being made of needs and ideas. During 1954 work was started on the development of a fully portable, lightweight instrument shelter, a solenoid-type recording anemometer, and an electrically driven fan psychrometer.

Fuel-moisture-stick manufacturing under the supervision of the forest-fire laboratory was continued at the Spokane Warehouse. All fuel-moisture sticks for the western United States and Alaska are manufactured here. Testing of fuel-moisture sticks for performance characteristics was continued at the Priest River Experimental Forest.

Arrangements were made in 1954 for additional forest protection agencies in the Inland West to take advantage of the instrument calibration and repair service at the forest-fire laboratory. The wind tunnel and other instrument facilities at the laboratory can now serve a much greater area in maintaining high standards for fire-danger-rating systems. This program, financed by the agencies operating fire-danger stations and supervised by fire-laboratory technicians, is an important factor in providing better research data and operational information on fire weather in the Inland West.

LIGHTNING FIRE RESEARCH

Project Skyfire--the broad cooperative program of lightning fire research--completed its second field season. During 1954 several additional agencies joined in various phases of the research program. Highlights of the 1954 field season were the conducting of a cloud survey in the northern Rockies, Oregon, and California; the pioneer operations of the Munitalp-University of Washington-Forest Service mobile atmospheric-research laboratory; and special synoptic analyses of lightning storms and the jet stream.

Cooperative Research

Project Skyfire is aimed at (1) gaining basic information on lightning fires and storms, and (2) testing the possibilities of preventing or reducing the severity of lightning fires through cloud modification. These aims are being accomplished through a cooperative research program. At the end of 1954 there were 15 private, state, and Federal agencies participating in the program, including 3 national forest regions and 2 forest experiment stations.

The Munitalp Foundation, Inc., along with the Forest Service is the primary backer of Project Skyfire. The Foundation's major contributions include financing construction of the mobile atmospheric research laboratory, furnishing of time-lapse motion-picture cameras, film, and film processing, general technical supervision of meteorological phases of the project, and assistance in financing training schools and publications. Mr. Vernon Crudge, Executive Director of The Munitalp Foundation, is assisting in general planning and supervision of the project. Dr. Vincent J. Schaefer, Director of Research for the Foundation is codirector of Project Skyfire. He maintained his field-season headquarters at the Priest River Experimental Forest and assisted in all field phases of the project. Dr. Paul B. MacCready, Jr., Research Associate of the Foundation, assisted at the Forest-Fire Laboratory and at Priest River on many project activities during 1954. Donald Fuquay, of Munitalp and the University of Washington, is the designer and operator of the mobile atmospheric laboratory.

The U. S. Weather Bureau is assisting in many phases of the project including special synoptic analyses, the furnishing of jet stream and other weather maps, special forecasting, and assistance in general analyses of cloud-survey data. The fire-weather office at Missoula, under the direction of W. R. Krumm, is one of the main nerve centers of the project where cloud-survey information is received daily by radio from the Skyfire network of fire lookout stations. The fire-weather forecasters at Missoula and Pendleton, Oregon, prepare special reviews of lightning-storm periods. General assistance on the California cloud survey was given by the Western Fire-Weather Coordinator at San Bruno, California. During 1954 the Chief of the Weather Bureau assigned Mr. Kenneth Nagler, Research Meteorologist, to assist in special synoptic analyses of lightning storms and the jet stream.

University of Washington.--The Department of Meteorology and Climatology has assisted in the designing, construction, and operation of the mobile atmospheric-research laboratory. The laboratory has now become a full-time project for Meteorologist Donald Fuquay.

Montana State University.--Mr. Donald Drummond of the School of Forestry assisted Project Skyfire throughout the 1954 field season in the training and inspection of personnel at cloud-survey stations.

The University of Idaho has constructed a cloud chamber for studies of atmospheric nuclei.

The Boeing Airplane Company is assisting with unique, high-altitude photography of clouds and lightning storms.

The General Electric Research Laboratory is furnishing instruments and special technical assistance. Dr. Irving Langmuir assisted in the initial field activities and is a technical advisor to Project Skyfire. Mr. Raymond Falconer is experimenting with special long-range forecasts for part of the project area.

The National Park Service is operating Skyfire cloud-survey stations at Yellowstone and Yosemite and is assisting in providing data on lightning fires.

The California State Division of Forestry is operating experimental cloud-survey stations in California.

The California Forest and Range Experiment Station assisted in planning the California cloud-survey network and in training personnel.

Forest Service Regions 1, 5, and 6 are operating cloud-survey stations. In Regions 1 and 6 a radio network is used to transmit daily cloud and lightning data to the Forest-Fire Laboratory at Missoula.

Cloud Survey

During the 1954 fire season a cloud survey was conducted from 17 forest-fire lookout stations in northwestern Wyoming, western Montana, northern Idaho, and northeastern Oregon. Later in the fire season eight stations were added in California. The purpose of the survey is to chart the development, movement, and action of clouds and lightning storms. This information is expected to assist in providing a better understanding of the life cycle of lightning storms. It is also providing information on general fire weather and fire behavior. Time-lapse motion-picture cameras were again operated at key stations.

Prior to the 1954 fire season a cloud-survey manual was prepared as a guide for personnel at fire-lookout stations. This manual proved very helpful in identifying and measuring clouds and in observing lightning storms. It is planned to revise and print the manual in 1955.

The 1954 Project Skyfire training school held at the Priest River Experimental Forest was attended by 25 lookout observers. The experience in conducting schools of this type indicates that fire-lookout personnel can be instructed in a relatively short period to identify and measure clouds and to record vital information on lightning. These techniques are expected to become important factors in the operation of future fire-lookout systems in lightning areas.

Analysis of the 1954 cloud-survey data has only begun, but it is now known that several significant factors have been developed. Perhaps the most important is the development of a workable cloud-survey technique. Other significant results include the development of new methods for measuring cloud heights and speeds. Research Paper No. 35 prepared in November 1954 summarizes the cloud survey and general Skyfire results to date.

Mobile Atmospheric-Research Laboratory

The first field operations of the mobile atmospheric-research laboratory were made in 1954. The laboratory as now equipped can measure

and record such factors as wind velocity and direction, dew point, temperature, incoming and outgoing radiation, salt particle content of atmosphere, condensation nuclei, ice-forming nuclei, sky brightness, and atmospheric electricity. Field tests of ability to measure these factors were made at several valley-bottom and mountaintop locations. As a result of these tests a few minor revisions and improvements will now be made. The tests show that the laboratory is an excellent unit which will permit pioneer studies to be made of many important phases of the lightning-fire problem. The mobile laboratory demonstrated its over-all usefulness in forest-fire research when its instruments measured and recorded heat and weather factors during the experimental burning of logging slash at the Priest River Experimental Forest.

During 1955 the mobile laboratory will be used to record atmospheric factors in lightning-storm areas. The laboratory will operate at key mountaintop locations during much of the 1955 fire season. If possible, the laboratory will be used in studies of micrometeorological factors on going fires.

LOGGING SLASH RESEARCH

The Priest River Field Laboratory

The cooperative University of Idaho-Forest Service logging-slash research project has been under way for almost 3 years. Forest Service efforts have centered at the Priest River Field Laboratory. To date 161 plots have been burned experimentally, containing 3 weights per acre of slash of the Region's 9 commercially important species. The plots burned in 1954 were immediately recharged with slash for burning in August, 1955. At that time burning experiments will have been completed on current year's and 1-year-old slash of all 9 species. After being recharged in 1955, the plots will be held for burning after the slash has aged for 5 years.

Experimental burning has yielded valuable new information on the behavior and heat of slash fires. In 1954 the University of Washington, Department of Meteorology and Climatology, assisted in the Priest River slash-burning program by providing instruments and technical advice in measuring heat radiation. This valuable cooperation is expected to continue. In addition to experimental burning, initial research has been completed on moisture content and rate of drying of freshly cut slash, and on amount of slash contained in tree crowns in relation to species and size of tree. The tree-crown study has been carried out in cooperation with the California Forest and Range Experiment Station. The following is a general summary of the results to date:

Rate of Spread of Slash Fires

The effect of quantity.--The amount of slash present, measured in terms of tons per acre, is the major factor affecting rate of spread

in the current year's slash. As slash ages, weight per acre remains a major factor, but becomes relatively less important.

The effect of species.--In current year's slash, species has a negligible effect on rate of spread in moderately to very heavy slash concentrations. In light concentrations of slash of species which lose their needles in drying, however--e.g., western hemlock and Engelmann spruce--fire will spread hardly at all. Species becomes a more important factor as slash ages because the quantity of fine fuel is reduced at different rates in different species.

The effect of age.--Aging for 1 year reduces rate of spread in most species of slash. So far the least apparent reduction--practically none--has occurred in white pine slash; the greatest in Douglas-fir slash. The main cause of change in rate of spread is loss of needles by some species. Compaction is a secondary cause which is relatively unimportant the first year. Heavy concentrations of species which lose their needles immediately after cutting or which do not lose them within the first year burn just about as fast and hard as when they were first laid out. Some reduction occurs in rate of spread in light to medium concentrations.

The effect of rising humidity.--An increase in humidity quickly reduces rate of spread in light and medium slash concentrations. Rate of spread in heavy concentrations is not affected significantly within $1\frac{1}{2}$ to 2 hours after humidity begins to increase.

Quantity Measurement of Slash

Calculation of weight per tree.--Ovendry weight of a tree crown can be expressed mathematically, and hence graphically, as a function of d.b.h. and length of crown. For a single tree the calculation of ovendry weight may be very appreciably in error; but for the area of a timber sale, for example, the calculated total weight of slash which would result from cutting the stand should be sufficiently accurate to support an area flammability rating and to serve as the basis for a slash-disposal plan. In young merchantable and mature stands, amount of slash per tree of a given size is roughly proportional to the tolerance of the species: the more tolerant, the more slash. This picture may be less true in overmature stands since some intolerant species, notably ponderosa pine, develop large branches containing a disproportionate amount of wood.

Moisture Content of Slash

The starting point.--Freshly cut branches and fine twigs usually have a moisture content of 100 to 150 percent. The moisture content of larger branches and the trunk is reduced in proportion to the amount of heartwood present. The moisture content of heartwood may be as low as 30 percent.

Drying of fine material.--Needles and fine twigs on lopped branches fully exposed to the sun dry to 10 to 12 percent moisture content in about 2 weeks of midsummer weather; those in partial shade, in 3 weeks; those in full shade (south slope) in 4 weeks. Much more time is required if the branches are attached to the trunk of a large top. Those in full sunlight or half-shade dry to 12 percent in about 6 weeks, while those in full shade still contain between 95 and 100 percent moisture at the end of 3 months.

Drying of heavy material.--The trunk of a large top begins to dry as soon as it is cut. Moisture from the sapwood goes both into the air and into the drier heartwood. At the end of 5 to 6 weeks moisture content is approximately uniform throughout the piece. Heavy material in the sun or partial shade dries to about 30 percent moisture content in 3 months; in full shade, to about 40 percent. Normal warm-season precipitation during this initial drying period has no discernible effect on decline in moisture content.

Slash-Disposal Methods

Chipping.--Rate-of-spread tests showed that chipping slash reduced flammability to the point where the chipped material would burn actively only during the early afternoon of a dry, hot day. While experimental chipping was very costly, experience elsewhere indicates that this method of slash disposal may prove to have utility in special situations in the northern Rocky Mountains.

Roofing slash piles.--Covering hand-made slash piles with building paper was found to save 1 or 2 cents a pile in burning costs, over and above the cost of the paper. A greater advantage of roofing should be improved ability to schedule burning and to burn when fires cannot spread. Roofed piles ignite readily and burn out well in very wet weather.

FOREST ECONOMICS RESEARCH

The new surge of industrial and economic development occurring in the Rocky Mountains from Canada to Mexico places greater emphasis on the work of the Division of Economics. We have both a big Forest Survey task ahead and an important responsibility for economic studies.

FOREST SURVEY

Although the job of inventorying the forests of the United States was begun about 1930, major emphasis of the survey in the past has been in other parts of the country. Only in North Idaho and western Montana in the Rocky Mountain region was the timber industry development sufficient to justify surveys in the 1930's. As a consequence, although 75 percent of the forest area in the United States has now been covered at least once by the Forest Survey, only 31 percent of the forests in the eight Rocky Mountain states has been inventoried. Montana has been completely covered. It is hoped that the timber inventory of South Idaho will be finished in 1955 to complete that state also. But nothing has been done in Wyoming, Colorado, Arizona, New Mexico, Utah, or Nevada. As a matter of fact, these six states constitute the one major block of unsurveyed forests in the continental United States. Two factors make it important to complete the survey in these states before many more years have elapsed. One is the growing interest of the timber industries in the commercial forests of these states. The other is that in the absence of survey data the six states are a soft spot in the Nation's timber inventory knowledge.

In 1954 about 3 percent of the uninventoried area in the eight Rocky Mountain states was covered by the Forest Survey. Field work was completed on approximately 2.3 million acres of forest land in Bonneville, Butte, Custer, Fremont, and Lemhi Counties in Idaho. This brings the total surveyed area south of the Salmon River in Idaho to 9.1 million acres. Approximately 1.7 million acres more are yet to be inventoried there. When this area has been inventoried a comprehensive statistical report for South Idaho and analytical report for the entire state will be prepared. Historical and other material are now being assembled for the report.

We plan to move into Wyoming during the coming year and also lay out detailed plans for the Forest Survey in the rest of the Rocky Mountain area.

In an effort to speed up office work we now use a punch card system exclusively for compiling areas and volumes. We are also studying ways and means for streamlining field work. In cooperation with the Washington office of the Forest Service and the California Forest and Range Experiment Station, a study of field techniques for type mapping

and area determination was instituted several years ago. Comparisons and tests of ground mapping and aerial photo delineations of timber types will provide information on the relative costs and accuracy of the two methods.

As part of this same effort to develop better inventory procedures an expert photogrammetrist, Karl E. Moessner, was added to the staff to assist Forest Survey personnel in the use of aerial photographs and to carry out research in this important field. He was formerly associated with the Central States Forest Experiment Station at Columbus, Ohio. He has begun studies relative to problems in aerial photo interpretation techniques. Among other things these studies will attempt to determine whether techniques of stand measurement, dot sampling, and aerial estimating now being used in the eastern United States are feasible for surveys in the Rocky Mountain area. It is expected that the services of this photogrammetrist will not only improve the efficiency of the Forest Survey but also result in more and better use of aerial photographs by national-forest administrators and land managers in general.

While pushing forward with the initial survey in the 6 states, we are conducting reinventory or maintenance surveys in those areas covered some years ago. A reinventory of North Idaho was completed several years ago. A maintenance survey is now in process in western Montana. Approximately 1 million acres of forest land in Lincoln, Mineral, and Sanders Counties were covered during 1954, bringing the total resurveyed area in Montana to 2.6 million acres. It is hoped that the reinventory of these three counties will be completed in 1955.

In connection with its Forest Survey activities the Division of Economics has conducted periodic canvasses of the timber cut for various products. In 1954 the only major project of that sort was a survey of pole production in 1953 conducted in cooperation with the Rocky Mountain Pole and Treating Association. This pole production information will be published early in 1955. The canvass showed that in 1953 approximately 414,000 polos were produced in the Northern Rocky Mountain region which consists of northeastern Washington, North Idaho, and Montana. The proportions of poles cut by species were as follows:

Western redcedar	46.3 percent
Lodgepole pine	31.1 "
Western larch	21.8 "
Douglas-fir	.8 "

The total output declined from 1952, although lodgepole pine pole production increased.

ECONOMIC STUDIES

Prior to consolidation the Northern Rocky Mountain Station and the Intermountain Station each had one man engaged in economic studies. In the former he was concerned primarily with forest economics problems, and in the latter with rangeland problems. We feel the combining of these two undermanned activities will lead to a considerably stronger program than has been possible in the past. As a first step toward developing a well balanced program we have been engaged in a reappraisal of the economics problems relating to wild land management and development. Forest Service administrative personnel of the Intermountain region were contacted to get their ideas on needs for economics research. Their response was excellent and these suggestions were added to those made by personnel of the Northern Rocky Mountain region in 1952. These suggestions are being studied in the light of our finances and capacities, and actual studies will be started in 1955.

In 1953 the Station published Research Paper No. 31 to provide up-to-date facts on the location, extent, and use of the wild land resources in the Intermountain region. The supply of this paper is now exhausted so a completely revised edition, adding a section on statistics for the Northern Rocky Mountain region, was prepared by J. C. Lammi. It will be published early in 1955.

In cooperation with other agencies and individuals, and under the general sponsorship of the Montana Conservation Council, this Station helped conduct the 1954 Montana Conservation Caravan. This Caravan is a 1-week bus trip by teachers, bankers, farmers, legislators, and others interested in conservation through a portion of the state for the purpose of studying the natural resources. S. Blair Hutchison of this division was chairman of the Caravan, and George R. Fahnestock of the Fire Research Division carried much of the responsibility for developing a Caravan guide book. The principal interest of the Station was in this guide book. There has been a particular need to develop more effective tools for teaching natural resources conservation in both grade and high schools. Therefore the guide book, "Natural Resources--A tour in western Montana," represents an experiment in the presentation of resources material for teaching purposes. The Montana Conservation Council has made 500 copies available to the schools in the state, where it is being tested.

RELATED PROJECTS

At the request of the Foreign Operations Administration of the State Department, and at their expense, Harry W. Camp made a trip to Iran the latter part of the year for the purpose of helping that country organize a survey of its 7 million or so acres of forest along the Caspian Sea. His assignment, which started in November, will extend through February 1955.

During 1954 the Experiment Station completed its collection and compilation of forest statistics in connection with the Forest Service's Nation-wide Timber Resource Review. In addition the Division furnished one man to the Washington office for part of the year. He was engaged in analysis of the long-range timber outlook in the United States as a whole.

FOREST UTILIZATION SERVICE

Each year sees an increasing volume of forest products flowing from the Intermountain area into the Nation's wood-using markets. Lumber is the principal commodity but veneer, plywood, mining timbers, pulpwood, poles, piling, and other products, are on the increase. Numerous new sawmills and other wood-processing plants were built during the past year with the biggest developments taking place in Montana. New plywood, veneer, pulp, chipboard, and pulp chipping capacity was also added to the area during the past year. This upsurge in sawmilling capacity has increased the need for research in two of the Region's basic utilization problems, profitable use of tremendous volumes of wood residues at sawmills, and substitution for ponderosa and white pine of species such as lodgepole pine, mountain Douglas-fir, Engelmann spruce, cottonwood, aspen, and alpine fir. This will alleviate overcutting of these two valuable pines.

Most of the Intermountain forests were overripe when lumbering started and harvest has not progressed fast enough to forestall catastrophic insect damage. Billions of feet of virgin lodgepole pine and Engelmann spruce have died. To allow this material to go unused will deprive the regional industries of 60,000 man-years of payrolls. Research is needed on improved mechanized methods of harvest and on industrial uses for this vast woodpile.

UTILIZATION OF BEETLE-DAMAGED SPRUCE

Field work for the last of a series of Engelmann spruce depreciation studies carried on during the past two years was completed in October at the J. Neils Lumber Company mill in Libby, Montana. The objective of these milling studies was to determine elapsed time between infestation of the trees by beetles and profitable salvage for lumber.

Spruce logged in August 1953, from 1952 beetle-struck dead trees, dry-decked at Libby over winter and milled July 3, 1954, showed about the same deterioration as spruce logged in August 1954 from 1952 beetle-struck dead trees decked at Libby and milled October 2, 1954. Fall-down in value because of shrinkage and grade depreciation due to bug defects amounted to 20.7 percent. Of this figure, 3.2 percent was due to shrinkage. It was concluded that 2-year-old beetle-struck dead trees still produce good lumber with a profit margin. However, since the summers of 1953 and 1954 had no extremely hot weather and frequent rains were the rule, depreciation from checking was perhaps unduly retarded.

Foresters are hoping for moderate summer temperatures and frequent rains in 1955, such as occurred during 1954, to make possible salvage

of material that might otherwise not be suitable for lumber. Bug-killed spruce will in many instances be suitable for pulp and paper production for about 15 years.

POLES AND POSTS

Strength tests of three Intermountain species suitable for transmission poles--western larch, western redcedar, and lodgepole pine--were started during the year at the Forest Products Laboratory under a cooperative program with the American Society for Testing Materials. The over-all A.S.T.M. program at the Laboratory also includes testing two other pole species, Douglas-fir and southern pine. There are three separate phases to the project. In phase 1, green short-leaf pine poles will be tested to determine the correlation between crib and machine testing. In phase 2, all species will be tested green to determine the correlation between the strength of green poles and the strength of small, clear specimens of wood. In phase 3, treated poles will be tested similarly.

Green western larch poles were tested last spring. Strength properties of full-sized poles were well correlated with strength figures obtained by testing small, clear specimens of the wood. Average strength property for this sample of western larch was equal to results of any previous tests made to date.

Spiral Grain in Transmission Poles

Western larch transmission poles with extreme left-hand twist or spiral grain show distortion of as much as 50 degrees. These transmission poles, installed the summer of 1952, are being observed at the Newport Pole Farm of the Inland Empire Research Center. Since the poles were installed in 1952, they should be at least reasonably well seasoned at this time. Recent observations indicate that poles with left twist, particularly those having an extreme left twist, are still the bad actors. (Extreme twist has been defined as that spiral having a departure of more than 1 inch in a longitudinal distance of 1 foot of pole.) The poles continue to twist in the direction of the spiral during the summer and untwist to some extent during the moister winter months.

Considerable confusion has resulted from the use of the terms "clockwise" and "counterclockwise" twist or spiral. These terms have been discarded and reference will be made in the future to spiral as "slopes to left (or right) upward" as observed from the foot of a pole or tree. It is planned to continue this study for a number of years to ascertain whether seasoning or aging of the pole has a stabilizing effect on the twist. It is also planned to conduct a post-mortem of poles to determine interior structural characteristics that might be related to left- or right-hand twisting.

Service Life of Lodgepole Pine Fence Posts

One of the earliest experiments testing the value of the chlorine and phenol combinations as a wood preservative was established at the Squaw Creek Ranger Station of the Gallatin National Forest near Bozeman, Montana, about 19 years ago. Reconstruction of the West Gallatin highway has necessitated removal of almost half the test posts. After 19 years of service they are in excellent condition. The treating solution consisted of tetrachlorophenol and gas oil. The computed solution strength was 3.22 percent tetrachlorophenol. This preservative, originally known as Dowicide 6, contained approximately 90 percent tetrachlorophenol and the rest of the soluble portion consisted of other chlorinated phenols, such as trichlorophenol and possibly some pentachlorophenol. It is hoped that this service test can be continued for at least 20 more years.

INDUSTRIAL DEVELOPMENTS

New Plywood Plant at Polson, Montana

The Polson Plywood Company, Inc., the third new plywood plant constructed in the Intermountain area in recent years expects to be in production within the next few months, producing 15 million square feet of plywood annually. This operation started about 4 years ago with a slicing operation at the Polson Lumber Company producing edge-grain pattern veneer from western larch flitches. The principal species used for rotary-cut veneer will be western larch, with smaller amounts of ponderosa pine. Sliced veneer will be produced from Engelmann spruce, ponderosa pine, and western white pine, and will be used for the knotty pattern of paneling. Exploratory work on all these species has been done by the Madison Laboratory. The Forest Utilization Service has been working with the Polson group since the inception of the plywood plant idea back in 1944.

Pulp Chips From Sawmill Residue

As the first unit of a hardboard plant being promoted at Missoula, the chip preparation plant has gone into production. It is equipped with a Diamond hog, operated by a 60-horsepower motor. The present total electrical requirement of the plant is about 175 horsepower. The plant has a capacity of about 50 units of chips (200 cu.ft. per unit) per 8-hour shift or about two carloads.

All softwood species common to this area except western redcedar are used, but no bark is tolerated. Raw material consists mainly of trimmer ends, about half of them being kiln-dried and the other half unseasoned. Cost of the raw material ranges from $2.25 to $3.00 per unit. Since the chips are being used in the sulphate process, chip specifications are rather liberal. Fines are screened out on a ¼-inch

mesh and anything is taken that will go through a $1\frac{1}{2}$-inch mesh. Chips are being purchased by the Potlatch Forests Pulp and Paper Mill at Lewiston, Idaho.

An extensive survey by the Forest Utilization Service indicates over 2,000 cords of chip material are available daily at railhead in the Intermountain area.

PUBLICATIONS

A. Departmental publications

HUTCHINGS, SELAR S. Managing winter sheep ranges. U. S. Dept. Agr. Farmers' Bull. 2067, 46 pp., illus. 1954.

Descriptions of methods of good management, including knowledge of forage plants, recognition of range condition, and practice of moderate and uniform grazing; economic benefits of good management; important forage plants.

PECHANEC, JOSEPH F., GEORGE STEWART, and JAMES P. BLAISDELL. Sagebrush burning--good and bad. U. S. Dept. Agr. Farmers' Bull. 1948, rev., 34 pp., illus. 1954.

Where, when, and how to burn sagebrush for range improvement; costs of burning; and range management practices needed to maximize benefits of burning. A revised, up-to-date edition of U. S. Dept. Agr. Farmers' Bull. 1948 published in 1944.

PECHANEC, JOSEPH F., GEORGE STEWART, A. PERRY PLUMMER, JOSEPH H. ROBERTSON, and A. C. HULL, Jr. Controlling sagebrush on rangelands. U. S. Dept. Agr. Farmers' Bull. 2072, 36 pp., illus. 1954.

Methods of controlling sagebrush including burning, plowing, railing, harrowing, beating, grubbing, and spraying, on various kinds of range; where and when to control sagebrush; and range management practices to use after sagebrush is removed.

B. Publications in scientific and professional journals, etc.

ANDERSON, I. V. Suitability of Rocky Mountain woods for veneer and plywood. Jour. Forestry 52(8): 587-591. 1954.

Volume available for plywood and suitability of western larch, ponderosa pine, Engelmann spruce, western (Idaho) white pine, mountain Douglas-fir, cottonwood, aspen, and white birch.

BAILEY, REED W., and G. W. CRADDOCK. Contributions of western public lands to conservation. Jour. Soil and Water Conservation 9(2): 59-64. 1954.

Birth of conservation stemmed from action taken on western public lands, including development of concepts of conservation with use, sustained yield, and multiple resource use; describes contributions of western lands to professional status of conservation.

BARROWS, J. S. Lightning fire research in the Rocky Mountains. Jour. Forestry 52(11): 845-847. 1954.

Summary of the objectives, organization, and first field activities of Project Skyfire: the lightning fire problem in the Rockies and a broad research program.

BARROWS, J. S. Project Skyfire. Proceedings Western Forestry and Conservation Assn., 45th Annual Forestry Conf., San Francisco, Calif., Dec. 1954.

Progress report on lightning fire research in western forests including a summary of the cloud survey in the northern Rockies, Oregon, and California, and of the mobile atmospheric research laboratory.

BLEAK, ALVIN T., and A. PERRY PLUMMER. Grazing crested wheatgrass by sheep. Jour. Range Mangt. 7(2): 63-68. 1954.

After 7 years' spring utilization of 88 percent, damage to grass was obvious, and Russian-thistle had increased markedly, in comparison with pastures grazed to 71 and 59 percent. Sheep days' use declined in all pastures, but most in the heavily grazed pastures, and in general differences in animal production paralleled trends in vegetation.

BOE, KENNETH N. Periodicity of cone crops for five Montana conifers. Proc. Mont. Acad. Sciences 14: 5-9. 1954.

An analysis of a 22-year record of cone crop observations made by the U. S. Forest Service, describing periodicity characteristics and seed production potential by geographic areas.

CRADDOCK, GEORGE W. Water yield from snow as affected by consumptive losses. Proc. Joint Meeting Western Snow Conference and Colorado River Basin Water Forecast Committee. 1954.

Decreasing forest and range plant cover increases sediment production and flood discharges more than annual water yields. Comparison of relative efficiency of four kinds of range plants in utilizing precipitation for herbage production, and precipitation available for runoff.

CURTIS, JAMES D. and DAVID TACKLE. Pulpwood moves east from the Targhee. The Timberman 55(9): 122-123. 1954.

An operation clear cutting lodgepole pine for pulpwood in southeastern Idaho, and the silvicultural implications of this kind of cutting in the lodgepole pine type.

ELLISON, LINCOLN. Subalpine vegetation of the Wasatch Plateau, Utah. Ecological Monographs 24(2): 89-184. 1954.

Presentation of salient characteristics of soil development and primary succession, and reconstruction of character of original herbaceous vegetation, both of which differ markedly from traditional concepts; and description of changes in soil and vegetation under livestock grazing.

ELLISON, LINCOLN, and J. E. COALDRAKE. Soil mantle movement in relation to forest clearing in southeatern Queensland. Ecology 35(3): 380-388. 1954.

Although landslides are common under sown pasture, on equally steep slopes under rainforest soil mantle movement is also very rapid, but less conspicuous. It is not known under which type of cover greater total displacement occurs.

EVANKO, ANTHONY B. Forage species for reseeding northeastern Washington rangeland. Northwest Science 28(2): 70-76. 1954.

Preliminary results of species adaptation and season of seeding tests on submarginal cropland at three locations.

EVANKO, TONY. State Cattleman "Dutch" Bremner gets help through Curlew District, Wash. State Conservation Districts News 3(1): 7. Jan. 1954.

Through artificial revegetation and improved management, production of forage on submarginal cropland has been increased many fold, relieving grazing pressure on native ranges.

EVANKO, TONY, and JOHN ARMSTRONG. Reseeding the range. Washington Farmer 79(3): 5. Feb. 9, 1954.

Results of forage species adaptation and methods tests at three locations in northeastern Washington.

FAHNESTOCK, GEORGE R. Roofing slash piles can save--or lose--you dollars. Fire Control Notes 15(3): 22-26. 1954.

Slash piles covered by 4' x 4' building-paper roofs were burned during extremely wet fall weather on the same day as unroofed piles. It was found that 70 percent more roofed than unroofed piles could be burned in a given period. Main advantage of the practice is that slash can be burned cheaply when there is no chance for fire to spread.

HARDY, CHAS. E. Sticks measure fire danger. Western Conservation Journal 11(1): 16-17, 28-30, illus. 1954.

Describes manufacturing use of sets of 1/2-inch wood cylinders in the measurement of forest-fire danger.

HELMERS, AUSTIN E. Precipitation measurements on wind-swept slopes. Trans. Amer. Geophys. Union 35(3): 471-474. 1954.

Measurements from standard and three modified 8-inch rain gages on 22° slope in Priest River Experimental Forest over 3 years. The three modifications are: (a) standard with horizontally mounted Alter windshield; (b) orofice cut to angle parallel to slope with no windshield; and (c) sloped orofice with windshield parallel to slope. Catch from the last agreed well with snow pack water equivalent measurements.

JOHNSON, PHILIP C. A feeding record of the ten-lined June beetle. Jour. Econ. Ent. 47(4): 717-718. 1954.

An unusual record of feeding on ponderosa pine foliage near Spokane, Washington by adults of the ten-lined June beetle, Polyphylla 10-lineata (Say).

JOHNSON, PHILIP C. A hibernation record of Ips plastographus Leconte (Coleoptera: Scolytidae). Canadian Ent. 86(9): 431-432. 1954.

An instance of the California pine engraver (Ips plastographus Lec.) hibernating in short tunnels in the sapwood of host trees was noted by the author in Montana. While it is known that some species of Ips overwinter as new adults in trees other than the larval hosts, the present record is believed to be unique.

HUTCHISON, S. BLAIR. Fitting big dams into little economies. Land Economics 30(4): 329-332. 1954.

The impact of large dams on local communities, with particular reference to the proposed Libby Dam on the Kootenai River in Montana. Proposes that impact costs be given the same consideration as installation costs in planning dam projects.

LAMMI, J. O. Review of "Economics of Agricultural Production and Resource Use," by Earl O. Heady. Jour. Range Mangt. 7(5): 228. 1954.

SQUILLACE, A. E., and R. T. BINGHAM. Breeding for improved growth rate and timber quality in western white pine. Jour. Forestry 52(9): 656-661. 1954.

Techniques and early results of intraspecies breeding for faster growth rates and better quality in western white pine. Progeny seedlings produced through controlled pollinations among selected trees varied considerably in total height and significantly, though not strongly, reflected the growth rate of their respective parents. Average annual height growth during the last 10 years appeared better for studying heritability than average annual height growth during the whole life of the parent trees. A technique for measuring phenotypic traits in relatively open-grown, young western white pine trees was devised which proved practical.

SQUILLACE, A. E., and R. T. BINGHAM. Forest genetics research in the northern Rocky Mountain region. Jour. Forestry 52(9): 691-692. 1954.

Brief descriptions of forest genetics research projects in the northern Rocky Mountain region and some tentative recommendations for the conduct of future research.

TACKLE, DAVID. Comments on the Baker automatic tree seed planter. Jour. Forestry 52(7): 530-531. 1954.

Conclusions drawn from field trials of the Baker planter, using ponderosa pine, Jeffrey pine, and lodgepole pine seed.

C. Miscellaneous processed reports

BARROWS, J. S., VINCENT J. SCHAEFER, and PAUL B. MacCREADY, Jr., Project Skyfire--A progress report on lightning fire and atmospheric research. Intermount. Forest and Range Expt. Sta. Research Paper 35, 49 pp., illus. 1954.

The lightning fire problem in the West and organization of a broad cooperative research project, giving initial results of the cloud survey and jet-stream study and a chapter on meteorological approaches to reduction of fire danger.

DENTON, ROBERT E. Midge damage affects Christmas-tree production in the Inland Empire. Intermount. Forest and Range Expt. Sta. Research Note 7, 4 pp., illus. 1954.

A tiny midge, previously not recorded on Douglas-fir, threatens the Christmas-tree industry in northeastern Washington, northern Idaho, and northwestern Montana. Referred to locally as the Douglas-fir needle midge, Cecidomyia sp., the insect spends its early life feeding on juice within the needles. Damage during 1953 is estimated to have cost the Christmas-tree industry over 1 million dollars.

HOLMGREN, RALPH C. Progress report for 1953. (Cooperative research program for revegetating the deer winter ranges on the Payette and Boise River Drainages, Intermountain Forest and Range Expt. Sta., Idaho State Fish & Game Department, and Boise National Forest, cooperating.) Mimeo., 12 pp., 1954.

Status of our knowledge regarding game winter range revegetation; recommendations for planting in the granitic foothill areas of southwestern Idaho; problems needing further study.

HOLMGREN, RALPH C. A comparison of browse species for revegetation of big-game winter ranges in southwestern Idaho. Intermount. Forest and Range Expt. Sta. Research Paper 33, 12 pp. 1954.

A test of 24 species. The 12 that survived are rated on seed characteristics, palatability to game, growth rate, height at maturity, and damage by grasshoppers and gophers. Bitterbrush appeared most promising.

HOUSTON, WALTER R. A condition guide for the aspen ranges of the Intermountain region. Intermount. Forest and Range Expt. Sta. Research Paper 32, 21 pp., illus. 1954.

Ratings in five condition classes based upon species composition and production of aspen understory vegetation and adjacent vegetation in openings, percent ground cover, and accelerated erosion.

HUTCHISON, S. BLAIR, GEORGE R. FAHNESTOCK, et al. Natural resources, a tour in western Montana. Montana Conservation Council, 78 pp., illus. 1954.

Natural resources of Montana and their management. Written as a guide to the 1954 Conservation Caravan, an annual trip sponsored by the Montana Conservation Council, and intended to be an aid to the teaching of conservation.

HUTTON, GORDON A. Montana Christmas tree shipments again hit 3-million mark in 1953. North. Rocky Mountain Forest and Range Expt. Sta. Research Note 137, 3 pp. 1954.

Numbers of Christmas trees shipped from various Montana counties by rail and by truck, and numbers shipped to various states in 1952 and 1953.

JOHNSON, PHILIP C. Logging damage affects bark beetle resistance of residual ponderosa pine stands. Intermount. Forest and Range Expt. Sta. Research Note 6, 4 pp., illus. 1954.

During sanitation-salvage logging in western Montana trees of high insect risk were cut leaving 66 percent (9,990 board feet per acre) of the original pine stand. During various operations, but mainly that of skidding, 6.2 percent (617 board feet per acre) of the residual stand was damaged in varying degrees. Extra care in logging is urged wherever beetle protection is a major objective.

LAMMI, J. O. Primary money income from range watersheds. Ph. D. Dissertation, University of California, Berkeley. Jan. 1954.

Two ways of measuring money income from range-watersheds are developed by use of national income accounting principles. The two measures are then compared in some range-watershed management situations in Utah to determine their probable usefulness as economic guides to managers of public lands.

LAMMI, J. O. Northern Rocky Mountain pole production in 1953. Intermount. Forest and Range Expt. Sta. Research Note 13, 3 pp. 1954.

Results of pole production survey by species, number, percent of total, and state of origin; numbers of poles by species by years, 1947 to 1953; percentages by length and A.S.A. class for each species.

LYNCH, DONALD W. Growth of young ponderosa pine stands in the Inland Empire. Intermount. Forest and Range Expt. Sta. Research Paper 36, 16 pp. 1954.

Tables based on age and diameter showing future 10-year cubic-foot volume growth for individual trees with correcting factors for mortality and converting factors for cordwood and board-foot volumes.

LYNCH DONALD W. What is an acceptable allowable error and sample size in sample log scaling and tree measuring? Intermount. Forest and Range Expt. Sta. Research Note 14, 5 pp. 1954.

A graph alinement chart based on total sale value, variability of volumes, and scaling costs, giving the appropriate sampling error in sample log scaling or tree measuring to meet the point of diminishing returns.

ORR, LESLIE W. The 1953 pine butterfly outbreak in southern Idaho and plans for its control in 1954. Intermount. Forest and Range Expt. Sta. Misc. Pub. 1, 12 pp., illus. 1954.

History, location, extent, type of damage, and plans for controlling an infestation of the pine butterfly, Neophasia menapia (F. & F.), which in 1953 occurred on 169,000 acres of ponderosa pine forest on the Boise National Forest. Identifying characteristics and habits of the adult, egg, larval, and pupal stages are described and illustrated.

PETERSEN, DAN LLOYD. Reinventory of surface soil and plant characteristics, Morris watershed. M.S. Thesis, Botany Dept., University of Utah, Salt Lake City, Utah (in cooperation with Intermountain Forest and Range Experiment Station). June 1954.

Changes in vegetation and soil between 1939 and 1953 on a nonflood-producing subbasin of Farmington Creek, Davis County Experimental Watershed. Plant and litter cover increased on previously lightly grazed lower portion of watershed, but only litter increased on previously heavily grazed headwater portion.

SCHMAUTZ, JACK E. Grass--Cafeteria style in southwestern Montana. Intermount. Forest and Range Expt. Sta. Research Note 12, 4 pp. 1954.

Preferences of cattle for 13 seeded and 2 native grass species on summer range. The natives were grazed lightly when several introduced species were grazed very heavily.

SQUILLACE, A. E. Engelmann spruce seed dispersal into a clear-cut area. Intermount. Forest and Range Expt. Sta. Research Note 11, 4 pp., illus. 1954.

During a bumper seed year sufficient Engelmann spruce seeds were dispersed as far as 9 chains from the timber edge to provide for adequate regeneration, but in fair or poor seed years seed fall at that distance may not be sufficient. Results suggest that about 20 chains should be considered the maximum width in planning the size of clear-cut blocks in Engelmann spruce.

TACKLE, DAVID. Lodgepole pine management in the Intermountain region--a problem analysis. Intermount. Forest and Range Expt. Sta. Misc. Pub. 2, 53 pp., illus. 1954.

A comprehensive analysis of problems inherent to the management of lodgepole pine forests in the Intermountain region. Includes a preliminary classification of lodgepole pine stands, supplemented by photographs and descriptions to aid in recognizing the classes in the field, and a list of suggested studies for a research program.

TACKLE, DAVID. Viability of lodgepole pine seed after natural storage in slash. Intermount. Forest and Range Expt. Sta. Research Note 8, 3 pp. 1954.

Germination tests of seed from unopened cones of all ages collected on the ground and up to 3 feet above ground in 6-year-old logging slash showed that seed from cones above ground had about twice the germinative capacity and germinative energy as seed from cones on the ground.

TERRELL, TOM T. Mortality of the Engelmann spruce beetle brood during the winter of 1953-1954. Intermount. Forest and Range Expt. Sta. Research Note 10, 9 pp., illus. 1954.

An average of 42 percent brood mortality occurred during abnormally low temperatures in January 1954 in western Montana and northern Idaho. Broods below snow level suffered lower mortality than those above snow level. No differences in mortality existed between north and south sides of trees. Evidence suggesting that larvae were more susceptible than adults was inconclusive. Somewhat greater mortality occurred at lower elevations. A predator and a parasite survived better than the host beetle.

WATT, RICHARD F. Mortality in second-growth stands of the western white pine type. Intermount. Forest and Range Expt. Sta. Research Note 9, 5 pp. 1954.

Records collected on 38 permanent sample plots showed mortality to be extremely variable, increasing with volume and age of the stand, and in the case of board-foot mortality, with site index. At 100 years of age, 10 percent of the total board-foot production, 22 percent of the cubic-foot volume, and 30 percent of the basal-area production had been lost through mortality.

WIKSTROM, J. H. Pulpwood production in 1952. North. Rocky Mountain Forest and Range Expt. Sta. Research Note 135, 1 p. 1954.

Results of 1952 survey by species and area of origin, in cords and percent of total pulpwood produced. Areas used in this report are western Montana, eastern Montana, north Idaho, and northeastern Washington.

WIKSTROM, J. H. 1952 log production for lumber and veneer. North. Rocky Mountain Forest and Range Expt. Sta. Research Note 136, 3 pp. 1954.

Log production for lumber and veneer by species, by state and county of origin, in board-foot volumes, and percentages of total production.

WILSON, ALVIN K. Delineating ponderosa pine volume and site quality classes from aerial photographs. Intermount. Forest and Range Expt. Sta. Research Paper 34, 10 pp., illus. 1954.

Suggestions for the use of stereograms in improving timberland sampling, based on experience gained from installing an experiment in ponderosa pine management which required delineating 3-volume-per-acre classes of timber on the ground. Aerial photographs saved considerable time and effort.

WINTERS, WAYNE STREET. Reinventory of soil and plant characteristics of Miller watershed. M.S. Thesis, Botany Dept., University of Utah, Salt Lake City, Utah (in cooperation with Intermountain Forest and Range Experiment Station). June 1954.

Describes changes in vegetation and soil between 1939 and 1953 on a formerly flood-producing subbasin of Farmington Creek, Davis County Experimental Watershed. All vegetation except perennial grasses increased in density. Conifers, aspen, tall shrubs, and shade-loving perennial forbs increased at the expense of low shrubs and grasses. There was an over-all increase in both area and depth of litter.

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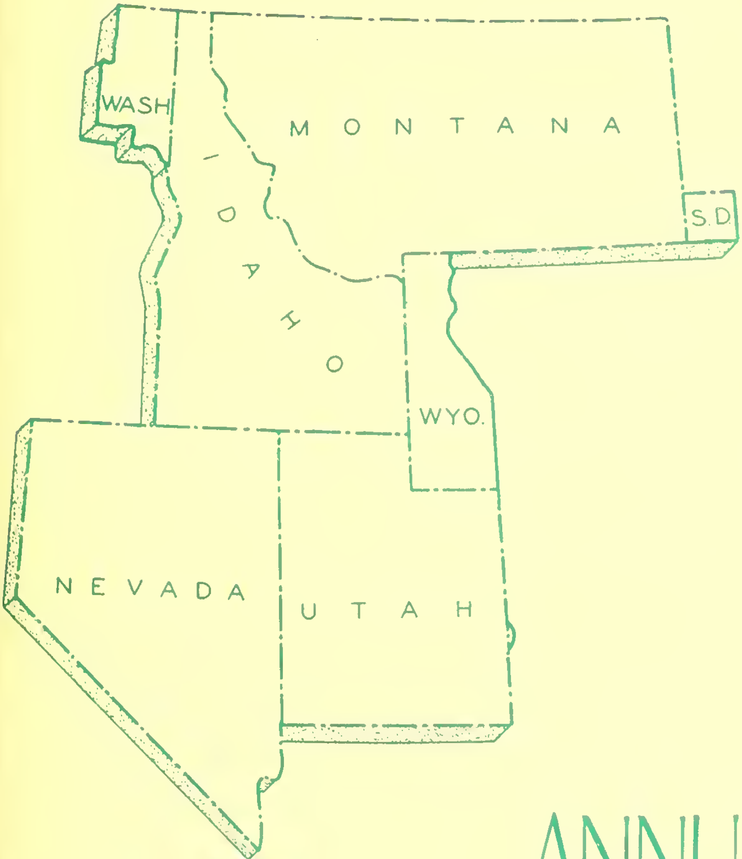
* Moved to Missoula, Montana from Coeur d'Alene, Idaho on January 1, 1955.



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ANNUAL REPORT 1955

INTERMOUNTAIN FOREST & RANGE EXPERIMENT STATION

FOREST SERVICE
U. S. DEPARTMENT OF AGRICULTURE

OGDEN, UTAH

REED W. BAILEY
DIRECTOR

CONTENTS

A LOOK AHEAD

> "You will see to it that the water, wood, and forage of the reserves are conserved and wisely used...and where conflicting interests must be reconciled the question will always be decided from the standpoint of the greatest good of the greatest number in the long run."

The instructions given by Secretary Wilson to the newly launched Forest Service fifty years ago were fundamental and prophetic. Much progress has been made within the framework of this philosophy and we can be sure that it will continue to serve well the future managers of our wild lands.

These instructions, however, did not specify how they could be carried out. How should the timber be cut and the forage grazed to assure perpetuity of these renewable resources? How should the forests and grazing lands be managed to protect the water supplies originating in them? Instructions did not spell out what forest and range practices were necessary to assure the attainment of that attractive and motivating slogan "the greatest good of the greatest number in the long run."

Nevertheless, we can truthfully say that important progress has been made, since those early stalwarts launched the national forest system, in all phases of forest and range land management and in all ownerships. Through trial and error, experience, and limited research, forestry has come a long way on the road of conservation through use.

On the basis of the record of the past fifty years, and the experience and knowledge we have gained, we can see in general outline the picture of forestry of the future, and it looks good. We are sure that the products and services of the Nation's forests and ranges will be in great demand. They will play an ever-increasing role in the economic, social, and spiritual growth of the country. They will be essential to that growth and will not be made obsolete by an atomic and chemical age.

The uses to which wood will be put in the future are limited only by the scope of our ingenuity and ability to juggle the molecules of cellulose. Wood fiber from inferior species of trees and wood scraps from our mills will be turned into an amazing array of cloth, paper, lacquer, plastic, and fiberboard products. Through wood chemistry will come products as varied as stock-feed molasses and industrial acid. Improved glues and new techniques will permit the creation of large materials of any shape from small cheap wood

pieces. We are now using laminated wood arches with spans as great as 200 feet. In the future we will see, in full production, laminated products ranging from baseball bats to bridge timbers.

As a result of the new uses of wood and the new processes, many so-called weed species of trees will become wanted and valuable. They will take some of the pressure off the present high-grade species. They will provide markets for small-sized billets, posts, and poles so that cultural treatment in young stands will be feasible. The great array of marketable products will permit harvest cuttings of whatever shape, size, form, or variety best suits the needs of management. With all the new uses for inferior materials, high-grade timber will still have an important place and its need in the Nation's construction program will increase as indicated by the present demand and price of large clear boards. In growing better wood and growing it faster, we will employ the science of genetics and during the next fifty years trees improved through breeding and selection will be in production.

Recreational use of forest lands will increase beyond the imaginations of most of us. With the growth of urbanization, use of the woods, streams, lakes, and mountains to satisfy the esthetic and spiritual needs of men have increased manyfold during the past fifty years, and such needs will increase in geometric proportions during the next half century.

Range use reached the saturation point early in the history of western grazing. But the demand for forage, by both livestock and game, has steadily increased over the years. Although many adjustments in the numbers of animals grazed are yet to be made, rehabilitation of deteriorated range lands through reseeding and improved management practices gives fair promise of increased use in the future. Grazing of livestock and big game is the only means of harvesting the valuable forage crops that large areas of lands in the West are capable of growing. Future plans call for reaping this harvest on a sustained yield basis.

Water, the most essential product of our wild lands, continues to be a critical need and will be a limiting factor in our future progress. Our rapidly growing population, with the need for more and more food, and the industrialization of all parts of the country, are calling for more and better quality water. Multi-million dollar programs for development of major river systems illustrate the extent to which the public will go and must go in the development of its water supply. But dams alone will not do the job of water conservation. The forest and range lands on which the waters originate must be made to function to regulate streamflow and control sediment production. We know now that the manner in which timber is cut, roads are built, and animals--whether domestic livestock or wild game--are grazed on the watersheds of our streams, have much to do

with maintaining the useful life of reservoirs. Forest and range use plans must be geared to the requirements for production of usable water.

This is critically impelling and cannot be denied if our communities and industries are to survive and grow. The small beginnings in watershed management recently launched will become the principal objective of utilization and management in the future throughout much of the country. Water conservation programs of the future will be unified and they will provide not only for well-constructed multiple-use dams but, in addition, for scientifically designed forest and range use practices. The new era of wild land management will be marked by practices designed to make forest and range lands fully productive. Uses will be based on technically sound consideration of the hydrologic as well as productive limits and potentialities of the land.

The first fifty years in the life of the Forest Service has seen a marked trend in wild land management generally away from a long era of exploitation. These past practices had both good and bad results. They fostered a rapid movement of population westward across this continent and made available the timber and forage that were needed for a growing nation. But this exploitation left the nation poorer in reserves of timber, forage, and wildlife, in acreages of stable soil, and in the regularity and clarity of streamflow. Progress during the past fifty years is primarily to be measured in the stopping of abusive practices of exploitation and substituting for them such better practices as lay at hand or could be improvised. With the passage of time and as scientific research has provided better understanding, many of these early management practices have been improved.

Progress during the next fifty years will be measured primarily in terms of effective management. Future progress, as envisioned both by dreamers and practical-minded land managers, is predicated upon enlightened public attitudes, more and better trained technicians, and the acquisition of knowledge through research. Our experience tells us that education and research are basic. We live in a Republic where democratic practices must be fostered and protected. Research programs must be enlarged and strengthened. Although the general goals of wild land management have become clear, many methods and procedures, principles, and concepts must be worked out by the scientific method before these goals can be reached.

In the following pages, the Intermountain Forest and Range Experiment Station presents its annual report, as it has done each year most of the forty years of its existence. These past reports reflect, each in its own way, our understanding of wild land problems at a particular time and the nature of progress being made. So it is with this report for 1958. For those who look back fifty years hence, may this report mark considerably less than the halfway point in a century of progress!

FOREST MANAGEMENT RESEARCH

A review of activities in Forest Management Research at the Intermountain Station during 1955 reveals a number of significant developments. One highlight, certainly, is the heightening interest in forest genetics research For several years the Station has participated actively in a program aimed at developing a blister rust-resistant western white pine in the Inland Empire. It has conducted field trials of hybrids produced by the Institute of Forest Genetics and carried out tree breeding projects in Montana and Idaho. Plans are now being laid for a possible future program of forest tree improvement through selection and breeding in southern Idaho. Local industrial and agency groups are interested and several meetings with genetics as the central theme have been held.

Another development deserving special mention is the increased effort being placed on regeneration studies. Launched last year with the assignment of a man primarily to this field of work, it is beginning to show results. During the past field season current research activity and status of regeneration knowledge, both natural and artificial, were reviewed for all major forest types in the Intermountain Station's area. As a result of this analysis, certain adjustments in program emphasis may be made. With insufficient resources to handle the job adequately alone, projects employing a cooperative approach are being organized. Both National Forest Administration and the forest industries have responded well to Station efforts in this direction. Several such coordinated studies are now under way.

Evident, also, during the past year is the increasing call for more and improved mensurational aids. Forest managers are asking the Station for better methods of determining site, for volume and yield tables, and for ways to estimate cull and defect. A closely allied interest in log grades is being expressed throughout the Intermountain area.

The above examples are simply indications of a very significant trend which became increasingly apparent in 1955. The virtues and wisdom of good forest management are being appreciated to a greater extent and are becoming more widely accepted in the area. Foresters and timberland owners want to manage their properties better and are turning to Research for facts and guiding principles. It is a healthy sign, and most assuredly a challenge to Forest Management Research at the Intermountain Station.

Selected items of progress from the Station's program in the Northern and Intermountain regions are presented below.

GENETICS

Breeding Blister Rust-Resistant Western White Pine of Good Growth and Quality

The western white pine breeding project is carried out in cooperation with the Spokane Unit, Blister Rust Control, National Forest Administration. For information on rust-resistance aspects of the project, the reader is referred to the latest annual report of this cooperator. Major items of progress in the vigor-quality phases follow:

1. Routine measurements on growth rate and crown form in progenies and grafted trees were continued. Large differences in growth rate and crown form and evidences of local ecotypes in progenies up to 4 years of age are still apparent.

2. The first group of progenies reserved for long-term studies of vigor and timber quality was outplanted last spring. Survival was not as good as desired, due primarily to winter damage of the stock in an off-site nursery at Missoula during the preceding winter. However, it is believed that sufficient numbers of seedlings survived to permit testing of most of the lots.

3. A series of flower induction tests was initiated. The main objective of these tests is to find the best means for stimulating early flowering in F_1 progenies in order to obtain second generation material as soon as possible. The studies will also yield information valuable for developing seed orchard techniques. The tests include: (a) Approach grafting of potted seedlings into the tops of 10- and 30-year-old trees. (b) A combined treatment of cultivating, fertilizing, and watering 10-year-old trees. (c) Approach grafting on hybrid rootstocks. A small-scale test made earlier showed that scions grafted onto eastern-western white pine hybrid rootstocks grew more rapidly than those grafted onto local western white pine rootstocks. (d) Fertilizing fruiting-age trees. (e) Cultivating, fertilizing, and watering seedlings with single and with all possible combinations of treatments. The technique used for top grafting was highly successful, 90 percent of the attempted grafts having made unions.

4. Cones produced in a selective fertilization test begun in 1954 were collected in the fall of 1955. Seed yield from the different crosses and the shape of the cone scales (see item 5 below) both indicate that some degree of selective fertilization (favoring crossing over selfing) likely occurred in at least one out of three tests involving different parents. The seeds will be sown in the spring of 1956. Since selfs are inherently smaller than crosses it is believed that a fairly reliable estimate of the amount of selective fertilization occurring will be obtained through segregation

of seedlings on the basis of first-year height. Parents used in the test were chosen on the basis of previous knowledge of the significant difference in first-year height of their crossed versus selfed progenies produced in the past.

5. Two tests designed to study variation in average seed weight of progenies produced through controlled pollination have been completed. These relationships were found to have a bearing on variation: (a) Seeds borne on shoots occurring in the upper and outer crown and on the south and west sides tended to be heavier than those borne in opposing portions of the crown. (b) Seeds borne on shoots containing larger numbers of cones tended to be slightly heavier than those on shoots having fewer cones. (c) Seeds in cones having relatively fewer sound seeds in relation to cone length tended to be heavier. The latter relationship suggested that pollen source could affect average seed weight indirectly through its effect upon seed yield. No significant direct effect of pollen source upon seed weight was found, however, and if such effects do occur they are likely to be small and easily obscured by environmental factors. Pollen source was shown to be associated with the average shape (width vs. length) of cone scales in some instances. Use of certain pollens resulted in scales which tended to be relatively narrow, while use of other pollens resulted in scales which tended to be comparatively wide. This is apparently an exemplification of metaxenia, or effect of pollen upon maternal tissues of the fruit, which has been shown to occur in some species (certainly in angiosperms), The study also demonstrated that in critical breeding experiments where it is desired that variation in seed weight and other traits be minimized, flowers should be carefully chosen, preferably through the use of an efficient statistical design. A followup test of possible metaxenial effects of pollen parents upon cones and seeds, especially the cone-scale shape, was initiated.

6. A test of osmotic pressure in seeds produced through controlled pollination conducted this year shows promise of being a useful tool in forest genetics work. Such tests have been reported as being effective in estimating genotypic traits in certain agricultural plants. The test as applied here involved cold water soaking, then germinating seeds on filter paper wetted with water or a weak sugar solution. Seed lots which germinated comparatively well in the sugar solution were considered as having a higher osmotic pressure, since they were able to imbibe water despite the adverse osmotic pressure of the germinating medium. The test was applied to 123 different seed lots, involving mostly intraspecies crosses and wind pollinations. Results showed a moderate inverse correlation of osmotic pressure with growth rate of progenies. Progeny seed lots of parents which apparently transmitted rapid growth rate in previous progeny trials (as measured in progenies up to 4 years of age) generally showed the lowest osmotic pressure values. Progeny

seeds of parents growing on the better sites displayed lower osmotic pressure than those from parent trees on poorer sites. This latter result furnished further evidence of the existence of local ecotypes in western white pine. Additional osmotic pressure tests are planned on wind-pollinated seeds collected from trees growing on a number of sites.

Field Tests of Hybrids

During 1955 field tests of lodgepole pine x jack pine hybrids produced by the Institute of Forest Genetics in California were maintained and new tests of locally produced hybrids were started. The new studies follow the same general design as the studies with hybrids from the Institute where growth and crown form are being tested. Locally produced lodgepole pine x jack pine hybrids (from the 1951 pollinations) were outplanted in two localities: Lubrecht Experimental Forest[1/] in western Montana and Priest River Experimental Forest[2/] in Idaho. Seed from the 1953 crosses were sown in Montana State Nursery at Missoula.

In another test, seed from other crosses made in 1953 using indigenous ponderosa pine seed parents were sown in the nursery. The species being tested are as follows:

Pinus ponderosa x *P. ponderosa* v. *scopulorum*
P. ponderosa x *P. engelmannii* (Apache pine)

Ponderosa Pine Variety Study

The Intermountain Station is assisting, along with other cooperators, in collecting material for a study of the racial strains of ponderosa pine being conducted by the Institute of Forest Genetics. Specimens of cones and foliage were collected at many points throughout the range of the species in the Station area. The study has two main objectives: (1) to provide information on racial variation of morphological and physiological characters in ponderosa pine, and (2) to accumulate a small supply of seed from various sources for cooperators who wish to conduct planting tests in their own localities of seed from other regions.

1/ Maintained by Montana State University.

2/ Maintained by Intermountain Forest and Range Experiment Station.

REGENERATION

Partial Girdling Stimulated Seed Production in Young Ponderosa Pine Trees

In 1954 a study was installed to test release and partial girdling as possible stimulation measures to increase seed production of ponderosa pine. Young, immature, and mature trees of good vigor were selected at different places in the Bitterroot valley in western Montana for the test. Although conclusive results will not appear before the end of the 1956 growing season or later, a preliminary examination has revealed that partial girdling of 50-year-old trees accounted for an immediate increase in cone production over untreated trees. The partial girdling consisted of removing a continuous 1- to 2-inch-wide band of bark and cambium encircling the tree except for a 4-inch bridge of bark left intact. The results shown in table 1 were obtained by climbing the trees and counting the cones.

Table 1. Immature cones on 50-year-old ponderosa pines the second growing season after treatment

Tree number	Immature cones: Girdled	Immature cones: Control
	Number	Number
1	78	0
2	66	1
3	14	0
4	56	0
5	2	0
Total	216	1

Partially girdled trees in the two older age classes appear to be showing similar trends. However, these sample trees were examined with binoculars and because of the small size of immature cones, differences could not be accurately determined.

Effects of release as a stimulation measure have not been determined, but will be evaluated after the cones mature. Factors such as soundness, seed weight, viability, and seed yield will also be studied in detail at that time.

Ponderosa Pine Seed Crop for 1956 to be Poor

Based upon a ponderosa pine seed crop forecasting study on the Kootenai National Forest, the 1956 seed crop will be poor. In July 1955, 78 tagged branches on the 6 remaining trees in the study (originally there were 8) had only 49 conelets available for ripening

in 1956, compared with 122 cones maturing on these same branches in July 1953 for the moderately good 1954 crop. All of the 1955 conelets were on only two of the trees. Assuming heavy squirrel cutting during the year of maturity, which has occurred in the past, and additional losses from other causes, a poor pine seed crop is forecast. Observations on the Lolo and Bitterroot National Forests indicate a poor seed crop for 1956 in these areas also.

Five-Year Results in a Lodgepole Pine Direct Seeding

In June 1950, an 11-acre plantation on a broadcast burned clear cutting in the Little Belt Mountains of central Montana was spot seeded to lodgepole pine. Rodents were poisoned in advance of seeding. Favorable weather prevailed, particularly during the germination period. By the end of the first growing season a successful plantation was established that had 74 percent of the seed spots stocked by one or more seedlings. Since original spacing was approximately 6 by 8 feet, there were 672 stocked spots per acre at this level of stocking.

During the ensuing 4 years there has been a slow, steady decline in the stocking of this plantation as shown in table 2. The average number of seedlings per spot has also decreased somewhat.

Table 2. Stocking of a spot-seeded lodgepole pine plantation at different examination periods

Date of examination	Stocked spots per acre	Seedlings per stocked spot	Stocked spots
	Number	Number	Percent
9-14-50	672	3.0	74
8-13-51	608	2.5	67
9-15-52	581	1/ -	64
6- 7-55	527	2.2	58

1/ No count made.

Height of the 5-year-old seedlings is somewhat disappointing, possibly because of competition afforded by the moderately dense stand of pine grass that developed by the end of the first year. Tallest seedlings averaged 0.6 foot and shortest 0.3 foot in height. Dominance is being asserted by numerous seedlings particularly where competition is reduced. Seedlings are expected to overtop the grass in another 2 years and should then grow more rapidly in height.

Lodgepole Pine Cone Opening Characteristics on Clear Cuttings

In July of 1955 investigations of factors affecting opening of persistent lodgepole pine cones in the logging slash on clear cuttings were started in central Montana. Previous studies had shown the importance of these cones as a seed source for natural regeneration. Furthermore, results indicated a tendency towards overstocking where slash had weathered during a summer season before piling for disposal. With greater knowledge about cone opening, methods of logging and slash disposal to control seedling density may be devised.

Some relationships are already becoming evident. Aspect and height above ground are important factors affecting cone opening. Not a single cone openly suspended one foot or higher above the surface opened during the growing season on either northerly or southerly aspects. Cones suspended 6 inches above the surface on southerly aspects partially opened but none at the 6-inch height opened on northerly aspects. Cones resting on the ground surface on southerly aspects opened rapidly and almost completely during the summer in contrast to those on northerly aspects where only a few cones opened during the same period.

On south-facing slopes, cones ranging from newly matured up to 10 years of age, lying on the ground, shed much of their seed during July and most of it by the end of August as shown in table 3. Trees were cut during May and June. Unopened cones were placed for testing on July 7.

Table 3. Proportion of total seed dispersed by lodgepole pine cones attached to branches placed unopened on a southeast-facing slope July 7, 1955, by period and cone age

Date of examination	Proportion of total seed dispersed by cones: Newly matured to 2 years old	3 to 9 years old	10 years old
	Percent	Percent	Percent
8-3-55	62.1	66.0	56.3
9-7-55	82.1	81.6	82.3
10-5-55	83.3	82.4	82.3

MENSURATION

Effects of Stocking on Site Evaluation and Yield

A manuscript was completed during 1955 on the effects of stocking on site measurement and yield of second-growth ponderosa pine. It will be published next year as a station paper.

Adjusted site index curves are presented for various conditions of stocking. Dense stocking retards height growth and thus influences the measure of site quality in such stands. Furthermore, the influence of dense stocking on height varies with site quality.

In addition to the adjusted site index curves, the manuscript presents a growth prediction system which considers the changes in stocking that overstocked and understocked stands pass through with advancing age.

Log Grading Plot Established

A plot of 71 mature ponderosa pine trees was established on the Boise Basin Experimental Forest to be used for training foresters in log grading. Personnel from the division of Timber Management (Region 4) and the Boise National Forest were assisted by a log grading specialist from Region 6 in assigning original grades to the logs in these standing trees. It is expected that log grading will eventually become a standard procedure in timber sales in Region 4, and this plot will help in achieving uniformity in the determination of log grades in standing trees.

HARVEST CUTTING

Results of Partial Cutting in Mature Western White Pine

Five-year records of sample plots in the Sheep Mountain Creek unit of the Clearwater National Forest show that net growth following partial cutting of this mature western white pine stand has been negative because of excessive mortality in the residual stand. Gross growth of the residual stand was good, averaging over 600 board feet per acre per year. However, excessive mortality reduced the net growth to minus 590 board feet per acre annually (table 4).

Table 4. Five-year growth per acre of mature western white pine stand following partial cutting

Stand	White pine volume	Total volume
	Board feet	Board feet
Before cutting	46,315	63,277
Removed	18,351	27,361
After cutting	27,964	35,916
5 years after cutting	24,293	32,967
5-year mortality	5,637	6,157
Gross increment	1,966	3,208
Net increment	-3,671	-2,949

Mortality was related to individual tree vigor even though caused for the most part by unusually high winds and buildup of beetle populations which might be expected to be less selective than normal levels of mortality. Records show that 13 percent of the good vigor trees, 20 percent of the fair vigor trees, and 35 percent of the poor vigor trees died during the period. In terms of board-foot volume proportionate losses were 12 percent, 18 percent, and 36 percent of the good, fair, and poor vigor classes respectively (table 5).

Table 5. Mortality in relation to vigor class of western white pine 5 years after partial cutting

White pine vigor class	Stand per acre after cutting		5-year mortality		Mortality percentage	
	Trees	Volume	Trees	Volume	Trees	Volume
	No.	Bd. ft.	No.	Bd. ft.	No.	Bd. ft.
Good	16.4	11,543	2.1	1,441	12.8	12.5
Fair	24.0	9,990	4.9	1,848	20.4	18.5
Poor	25.9	6,431	9.0	2,348	34.7	36.5
All classes	66.3	27,964	16.0	5,637	24.1	20.2

Vigor of the residual white pine stand in the Sheep Mountain Creek cutting declined even though mortality was lightest in the good vigor class. The proportion of white pine trees in the good vigor class dropped from 25 percent after cutting to 15 percent 5 years later.

Results of this study substantiate the conclusion from other partial cutting tests in mature western white pine stands that mortality is closely associated with tree vigor. They again emphasize the difficulty of predicting the occurrence of unusual mortality,

especially in a small area. The decline in vigor following cutting agrees with the results of other tests which show that partial cutting should be restricted to vigorous stands in which at least 40 percent of the trees fall in the good vigor class. In thrifty stands, partial cutting has increased growth by removing poor vigor trees which are susceptible to mortality. In unthrifty stands cutting 40 to 50 percent of the stand often accelerates stand degeneration.

Ponderosa Pine Production Study

When the last of the 4,311,500 board feet of timber cut on the 16 compartments of the ponderosa pine production study, Boise Basin Experimental Forest, was loaded out in January 1955, the major part of the installation of this study was completed. There remained some fire hazard reduction and erosion control work to be done before the operation could be closed.

Most of the slash disposal work for the second 8 compartments had been done in the fall of 1954 by personnel of the Boise National Forest; the part that remained was completed during the following spring and summer. The same crews completed several erosion control measures in skid trails.

The late completion of log hauling made it necessary for the operator to construct temporary dikes for erosion control on the spur roads in most compartments. When ground conditions became favorable, they were replaced by cross ditches designed for greater permanence.

A major effort in this field season's work was the reexamination of all the sample plots in the first 8 compartments of the study (logged in 1953). These plots were designed to furnish data for appraising the differences in damage to the younger age classes resulting from the two sizes of logging tractors and two reserve volume levels tested.

The surveying of all spur roads, begun in 1954 to permit revision of experimental forest maps and to allow the exclusion of road area from acreage and volume calculations within compartments, has been completed.

A survey of sawtree mortality following logging was made in the compartments logged in 1953. Mortality from all causes for the 2-year period totalled 20.1 M.b.f. for an average of 45 board feet per acre. Of this, 40 percent is attributed to lightning, 37 percent to insects, 14 percent to road construction, and 9 percent to other causes.

Board-Foot Growth in a 120-to 220-Year-Old Ponderosa Pine Reserve

A knowledge of the growth capacity of partially cut ponderosa pine stands is necessary for planning the initial harvest in remaining old-growth stands and forecasting probable yield from subsequent cuts of reserve sawtimber. Twenty-year results of a cutting study in western Montana show that 4,000 to 8,000 board feet per acre of vigorous, well-spaced trees of moderate size make up an ample reserve for growth. As in previous studies gross board-foot growth was found to vary with reserve volume.

Reserve volume	20-year gross growth
Bd. ft.	Bd. ft.
2,018	945
4,150	1,948
10,004	2,362

Individual tree growth was also studied. The vigor of trees making up the reserve stand and the amount of growing space made available to them proved to be important factors in growth acceleration (table 6).

Table 6. Twenty-year growth per individual ponderosa pine tree, 120 to 220 years old, following two degrees of cutting, by initial diameter and vigor class

Initial d.b.h. (inches)	78 percent volume cut		41 percent volume cut	
	Good vigor	Fair vigor[1/]	Good vigor	Fair vigor
	Board feet		Board feet	
12	69	-	55	30
16	122	-	77	58
20	175	-	99	86
24	228	-	121	114
28	282	-	143	142

1/ Values are the same as for good vigor trees. Since differences between adjusted means of the individual regressions were not significant, the data were combined into a single regression and the tabular values computed.

Information on growth of individual trees is valuable to the timber marker who must decide which trees to cut and which ones to leave for future production. Complete results of this study are to be published in a research paper in 1956.

Piquett Creek Experimental Forest

Volume estimates and initial samplings of insect risk were made in ponderosa pine at Piquett Creek on the Bitterroot National Forest. These estimates are to be used for determining the economic feasibility of developing a road system and making a light initial cut over the currently inactive experimental area. The work is being done in cooperation with National Forest Administration.

Volume data have not been completely analyzed. Risk data show that the proportion of trees in high-risk classes, as judged by Salman-Bongberg risk ratings, is 14.9 percent, about average for virgin ponderosa pine stands in the region.

Risk rating	Percentage of trees
I, low risk	35.1
II, moderate risk	50.0
III, high risk	13.1
IV, very high risk	1.8

Planning for the orderly extraction of the initial cut from Piquett Creek is to be continued in 1956.

Net Volume Growth in an Engelmann Spruce Reserve Stand

A small partial cutting made in an Engelmann spruce-alpine fir stand in 1924 now provides an opportunity to evaluate 30 years of growth on the residual stand. The stand is located in Spruce Creek drainage on the Kaniksu National Forest and occupies about 30 acres. It is part of a larger cutting involving 800 acres. The remainder of the area was cut on a group seed-tree basis. The original stand volume in the partially cut area averaged about 29,000 board feet per acre and the cutting removed 75 percent, principally in trees from the dominant and codominant crown classes. A little over 7,000 board feet per acre, chiefly Engelmann spruce, remained in the residual stand. Alpine fir was the principal associate with only minor quantities of other species represented. The age of the residual stand ranged from 118 to 140 years.

Despite the relatively small residual volume which was left, a reasonably good net growth was attained. The study shows that the Engelmann spruce made a net gain of 3,035 bd. ft. per acre in the 30-year period, 1924-1954, while the alpine fir sustained a net loss of 75 bd. ft. (table 7).

Table 7. Thirty-year gross and net growth and mortality per acre by species

Species	Reserve volume (1924)	1954 volume	Gross growth	Net growth	Annual mortality	Annual growth 30-yr. period Gross	Net
			Board	feet			
Engelmann spruce	5,906	8,941	4,255	3,035	1/41	142	101
Alpine fir	1,095	1,020	729	-75	27	2/24½	2/-2½

1/ 3.2 trees per acre.

2/ Values in these columns have been rounded off to the nearest 1/2 board foot.

Deductions for defect were not made from the volumes shown in the table because this factor was unknown in the residual stand. However, defect as determined by borings in the 1954 measurements amounted to 6 percent of the 1954 volume in Engelmann spruce and 48 percent of the alpine fir. Heart rots were chiefly responsible for the defect. Some alpine fir trees were observed in which the rot had consumed the entire portion of the stem which was present in the residual stand and had made inroads into the inner portions of the growth laid on since logging. This large defect in the alpine fir further accentuates the disparity in the growth results between the two species shown in the table.

Mortality in the residual stand has not been unduly high considering the usual lack of windfirmness of Engelmann spruce. However, the stand was situated just under the crest of a ridge in a reasonably well-protected situation. The annual mortality of 41 board feet per acre of Engelmann spruce was caused primarily by windthrow, while much of the mortality in alpine fir appeared to be caused by sunscalding and windthrow.

Diameter growth of residual trees responded to logging release but there was no substantial response until the second 5-year period after logging (table 8). National Forest personnel reported no evident improvement in diameter growth after an examination of the cutting in 1929 which confirms the slow start. The growth response was striking in the second 5-year period and showed a gradual increase throughout the first 25 years after logging. Trees in an adjacent uncut stand showed some improvement in diameter growth over the same period presumably as a result of climatic factors.

However, the trees in the cut-over stand showed a considerably greater improvement and the difference between the two reflects the response attributable to release.

Trees were classified into three vigor groups based upon crown size, shape, and condition in the 1954 examination. The analysis showed that the growth of individual trees was related significantly to vigor.

Table 8. Average diameter growth of trees in residual stand and uncut stand in relation to time since cutting

	Five-year periods after logging					
	0-5	6-10	11-15	16-20	21-25	26-30
	Inches					
Residual trees	.35	.51	.61	.63	.67	.62
Trees in uncut stand	.36	.38	.47	.48	.48	.51

Water Percolation into the Soil Following Cutting and Slash Treatment

Percolation rates during the fourth year following cutting in the larch-fir type at Coram Experimental Forest in Montana still vary by surface condition. The greatest reduction in percolation rates is apparent on tractor skid roads where extreme compaction of the soil has taken place. Broadcast burned areas show little change in percolation from the year immediately following logging, while scarified areas show only a slight improvement. On undisturbed areas percolation was only about half as much as during the year following logging.

The values in the following tabulation show the amount of time it took for 1 inch of water to disappear in a 6-inch infiltrometer ring after a presoaking period of 5 minutes:

Soil surface	One year after cutting	Four years after cutting
Undisturbed	0 min. 60 sec.	2 min. 9 sec.
Scarified	6 min. 30 sec.	5 min. 12 sec.
Broadcast burned	1 min. 38 sec.	1 min. 47 sec.
Tractor skid road	24 min. 27 sec.	59 min. 18 sec.

INTERMEDIATE CUTTINGS

With the rapid depletion of virgin timber stands, the logging industry is looking with greater interest to second-growth stands for future raw materials. Information on managing this young timber will be needed and the Intermountain Station is attempting to extend a greater proportion of its research effort in this direction.

Addition to Boise Basin Experimental Forest

Because suitable stands of advanced second-growth ponderosa pine are not available on the present Boise Basin Experimental Forest, steps were taken this year to locate a tract of suitable timber land that could be added to the experimental forest for second-growth studies.

The Bear Run Unit was chosen because of its excellent stocking of young ponderosa pine, its easy accessibility from the Boise Basin Experimental Forest headquarters, its national forest status, and its relative freedom from mineral entry. On its 1,200 acres can be found a desirable range of age classes and sites.

Preliminary mapping has been completed and the application report written. Steps will be taken in 1956 to get formal approval for the addition of the Bear Run Unit to the Boise Basin Experimental Forest.

Commercial Thinnings on Woodlots in Second-Growth Ponderosa Pine

Farmers' woodlots play an important role in the timber production of the Inland Empire. In acreage, woodlots constitute nearly one-fourth of the commercial forest land area, but their importance is greater than acreage alone indicates. Being generally at lower elevations, the woodlots usually are suitable sites for ponderosa pine, one of the most valuable species in the area. Furthermore, because of early logging operations which were concentrated on easily accessible pine lands, a second-growth crop has developed which, in many areas, is now approaching commercial size.

Research in the management of second-growth ponderosa pine in the Inland Empire includes five sets of plots testing three degrees of commercial thinning for sawlog material in 90- to 100-year-old stands. The three treatments in each set of plots include (1) a control plot with no thinning, (2) a light thinning removing about 30 percent of the volume, and (3) a heavy thinning in which 75 to 80 percent of the volume was removed.

Results of the first 5-year remeasurement of one set of these plots indicate that the light thinning improved the quality of the growing stock without sacrificing total growth. Volume growth on the lightly thinned plot and the control plot were practically equal. Both of these plots nearly doubled the growth on the heavily thinned plot. Average annual growth on the control, lightly thinned, and heavily thinned plots were 400 board feet, 398 board feet, and 237 board feet per acre, respectively, for the 5 years following thinning (table 9). The light thinning provided an intermediate income through the removal of poor-vigor and poorly formed trees without reducing volume growth.

Table 9. Five-year growth per acre following commercial thinnings in second-growth ponderosa pine

Stand	Heavy thinning		Light thinning		No thinning	
	Trees	Volume	Trees	Volume	Trees	Volume
	No.	Bd. ft.	No.	Bd. ft.	No.	Bd. ft.
Before thinning	95.1	15,535	90.2	16,586	104.1	18,809
Removed	27.1	10,498	24.3	5,062	-	-
After thinning	68.0	5,037	65.9	11,524	104.1	18,809
5 years after thinning	65.5	6,221	63.1	13,516	99.2	20,810
5-year growth	-	1,184	-	1,992	-	2,001
Average annual growth	-	237	-	398	-	400
Total yield	-	16,719	-	18,578	-	20,810

Precommercial Thinning in Western White Pine Stands

Analysis of data from a dozen tests of thinning young white pine stands have revealed several consistent effects of thinning. The tests included a variety of types and degrees of thinnings on a wide range of sites, ages, and species composition. The earliest test was established in 1914; the most recent one in 1936. The following general conclusions apply generally throughout the tests:

1. Thinnings should be light; i.e., they should remove not more than 20 to 25 percent of the cubic-foot volume. Heavier thinnings generally result in excessive loss in volume growth.

2. All thinning treatments stimulated diameter growth of dominant and codominant trees. Generally, diameter growth was directly related to degree of thinning except that light repeated thinnings increased diameter growth more than a single heavy thinning.

3. Thinning white pine stands also improved the quality and value of the residual stands by increasing the proportion of high-value white pine.

4. Thinning failed to increase stand volume growth.

Commercial Thinning in Western White Pine

Tests of commercial thinnings in western white pine stands suggest, again, that cuttings should be light for satisfactory growth and yield. Five plots located on excellent sites have been under observation for periods ranging from 10 to 30 years.

Plot 111 is situated on the Priest River Experimental Forest in northern Idaho. At the time of cutting in 1925 the stand was 62 years old and had a volume of 18,557 bd. ft. per acre (table 10). Fifty-nine percent of the volume was white pine and 35 percent western larch. Other species present were Douglas-fir, grand fir, western hemlock, western redcedar, Engelmann spruce, lodgepole pine, and ponderosa pine. A heavy thinning from above removed 54 percent of the merchantable volume leaving a residual stand of 8,533 bd. ft. Basal area reduction was from 207 to 139 square feet, or 33 percent. Since no check plot was established for this plot, its development after cutting has been compared to normal stand development for similar site, age, and percent of normality. Such a comparison discloses that if the stand had not been thinned, the average annual growth would have been approximately 166 bd. ft. greater and that the total yield 30 years after cutting would have been 4,981 bd. ft. greater than it has been. Apparently this heavy thinning reduced the growing stock too much for maintenance of normal production from the site.

Table 10. Board-foot volume development per acre of Plot 111 as compared to the theoretical development of the same stand had it not been thinned

	Plot 111, cut	Normal development of similar uncut stands
	Bd. ft. (Scribner)	
Original stand	18,557	18,557
Thinnings	10,024	-
Residual stand	8,533	-
Stand in 1955	31,457	46,462
Mean annual growth	764	930
Total production	41,481	46,462

In contrast to Plot 111, two 70-year-old stands in the Bearpaw drainage of the Kaniksu National Forest on which only 25 percent of the volume and 20 percent of the basal area were removed came close to or surpassed the growth rates of similar uncut control stands. Plot 150, supporting a stand of 41,155 bd. ft. per acre was thinned in 1937 and has since had an average annual increment of 769 bd. ft. per acre as compared to check plot 186 which has grown 713 bd. ft. per acre per year in the period 1942 to 1952 (table 11).

On similar plots in the same area (Plots 188 and 189) the mean annual growth on the check plot was 83 bd. ft. per acre greater than on the cut plot (table 11).

Table 11. Board-foot volume development per acre of Bearpaw commercial thinning plots - Kaniksu National Forest

	Plot 150, thinned (15-year-record)	Plot 186, check (10-year-record)	Plot 189, thinned (10-year-record)	Plot 188, check (10-year-record)
		Bd. ft. (Scribner)		
Original stand	41,155	52,309	40,688	42,279
Thinnings	10,488	-	8,933	-
Residual stand	30,667	-	31,755	-
Stand 1952	42,195	59,444	36,932	48,290
Mean annual growth	769	713	518	601
Total production	52,683	59,444	45,865	48,290

Light commercial thinnings can improve composition, provide a current cash income, and through the construction of logging roads open the stand for management purposes. Other generally accepted advantages of light and frequent thinning which may become more apparent in these tests later in the rotation period are larger tree sizes on the thinned plots, better quality, and increased usable production by salvaging potential mortality.

OTHER ACTIVITIES

Boundaries of the Boise Basin Experimental Forest were posted this year against mineral entry in order to protect the research value and investment in the area. Action to afford the same protection to other study tracts is now under way.

The entire staff of the Boise Research Center joined the fire fighting crews of the Boise National Forest in September to help in the control of the disastrous Robie Creek fire. This center also

cooperated with the California Station by collecting resin from 15 ponderosa pine trees on the Boise Basin Experimental Forest. The resin will be used by Dr. Mirov of the California Station in his extensive study of the chemistry of pine resins in the United States.

In this fiftieth year of the Forest Service, Forest Management Research publications by the Northern Rocky Mountain and Intermountain Forest and Range Experiment Stations were consolidated into an up-to-date list and published. The report (Miscellaneous Publication No. 6) includes releases by personnel in Forest Management Research at the two stations since the start of such work, publications by certain collaborators in this field, and selected material from other closely related divisions.

FOREST DISEASE RESEARCH

The program of Forest Disease Research at Intermountain Station was given a modest boost during 1955 by the financing of an additional position at the Inland Empire Research Center. The new man is to be assigned specifically to basic studies of white pine blister rust. One aspect of the investigation which will receive primary emphasis is the possible relationship of occurrence and spread of the disease to microclimate. The first phase of the project, now under way, consists of a problem analysis to be followed by the preparation of study plans by pathologists who have been working on pole blight and who know the forest type and the area.

Brief statements of progress in the effort to understand and learn how to control other major forest diseases of the Station area are presented in succeeding paragraphs of this report.

PONDEROSA PINE BLIGHT

Studies on the Elytroderma blight of ponderosa pine, which were initiated in central Idaho in 1948, were continued. During the past year added emphasis was placed on life history studies of the causal fungus, *Elytroderma deformans*, and possible methods of its control.

A number of small diseased pines (averaging 9 to 10 feet in height) growing on study plots have been under observation for the past five seasons. During that time progress of the fungus in the trees has been followed. Twigs and branches that were diseased in 1951, when the plots were established, have become reinfected annually since then. On the other hand, in these same trees the twigs and branches that were uninfected have remained free of the disease in practically all cases.

These findings suggest that some measure of control of the fungus may be obtained by pruning diseased branches. The experiment is being enlarged, therefore, to provide further information on this phase of the problem. Pruning could conceivably be done during the course of timber stand improvement operations that are conducted following logging in affected stands. In such stands that have been cut over and where timber stand improvement has been conducted it is not unusual to see pruned trees with but a few diseased branches remaining, all of which are within the lower portion of the crown. Removal of these branches at the time of the improvement operations would not add greatly to the cost of the work.

Another control experiment under way involves the application of fungicides. Work on this phase of the problem was started in 1954 when seven different materials were tested. Results obtained the

first year were regarded as inconclusive and consequently the tests were repeated in 1955. Laboratory studies on the fungus, conducted for the purpose of checking the results of the current season's spraying, revealed that the pathogen failed to develop normally. Very few of the spores were found to have matured. For this reason the effectiveness of the fungicides could not be measured.

All evidence to date strongly indicates that environment is highly important in the development of the fungus. For one thing, it is an organism requiring relatively low temperatures, particularly for germination of the ascospores. About mid-July in 1955 when the fruiting bodies that produce these spores were in a tender stage of development, maximum daytime temperatures suddenly jumped 20° to 25° F. above maxima for about 2 weeks previously. It is believed that the fungus was unable to withstand this abrupt change in weather conditions, thus accounting for the failure of the ascospores to mature. Some degree of natural control of the pathogen may therefore have occurred.

In those affected stands where studies on the fungus have been under way since 1948, the intensity of tree infection in 1955 was at about the same level as that occurring since 1952 and considerably below the peak years of 1950 and 1951. Mortality on study plots during the current year was confined almost entirely to trees whose growth rate for the past 15 to 25 years, longer in some cases, has been very slow. In addition to slow growth rate other common characteristics of the trees that succumbed are fire scars and root decay.

POSTLOGGING MORTALITY IN PONDEROSA PINE

Mortality following logging in ponderosa pine stands causes losses that in some cases are very severe. Results of studies conducted to date in southern Idaho show that much of this loss is caused by the root rot fungus *Fomes annosus*. The fungus is present and is under observation throughout much of that part of the Station area in Forest Service Region 4 (Intermountain Region). The mortality problem is complex in nature and involves in part insect and disease interrelationships. Some of the other factors (not all pathological) which may be involved in the death of the pines are: (1) lightning, (2) opening up areas in the stand by heavy cutting and thus suddenly changing the tree's environment, (3) fire scars which provide ports of entry for decay fungi attacking both roots and trunk, (4) root injury and destruction caused by machinery used in building logging roads, (5) logging road construction on steep mountain sides requiring deep cuts that reduce tree vigor by altering the former drainage pattern which results in soil moisture losses, and (6) cutting off oxygen supply to the roots of those trees growing on the lower sides of roads by covering the roots too deeply with soil removed from the road cut.

POLE BLIGHT OF WESTERN WHITE PINE

Progress in studies of this serious disease by Intermountain Station during the past year may be summarized as follows:

1. A coordinated soils-pathological research program to determine the cause of the pole blight disease of western white pine has provided the most promising leads to date. Rootlet mortality, studied in 26 plots in healthy and pole-blighted white pine stands of the 60- to 80-year-age class, showed a significant correlation between the degree of rootlet deterioration and the severity of pole blight. Rootlet deterioration is also correlated with effective soil depth and the available water-holding capacity of soils, the latter soil factor showing the highest degree of correlation. The severity of pole blight, when expressed as a percentage of the total white pine basal area affected, is significantly correlated with the three factors--effective soil depth, available water-holding capacity, and rootlet mortality.

2. Intensive field examination of soils in the white pine type may aid in evaluating the pole blight disease potential. It appears that deep, well-developed, medium- to fine-textured soils capable of storing more than 6 inches of available water in the top 3 feet of soil favor the continuance of white pine stands in a healthy state. Shallow, rocky soils, or deep soils with a dense hardpan near the surface, present a restricted root zone, low available water-holding capacities, and are more commonly found to support severely pole blighted stands.

3. An experiment to determine the effects of an artificially induced moisture stress on healthy pole-sized white pine has been initiated. By means of a shelter constructed about the trees and the confinement of lateral roots within the plot, slow soil drying will be effected to determine if pole-blight-like symptoms may be produced. After one summer, the soil beneath the shelter is reflecting a decreased moisture content when compared to the control area.

4. Study of lesions associated with pole blight of western white pine culminated in a report published in Forest Science. It suggests that reduced radial growth is always associated with pole blight and precedes both crown decline and lesion development. A marked reduction in radial growth in the lower stem usually occurs before crown symptoms of the disease appear. Although lesions are generally associated with pole-blighted trees, they apparently are not directly responsible for the progressive decline of diseased trees.

5. The grafting work, undertaken to determine whether or not pole blight may be caused by a transmissible virus, has been transferred to the University of Idaho. All data and grafted material

were transferred to this cooperator to complement its work on this phase of pole-blight research.

6. A study of the root system of trees in healthy western white pine stands indicates that general root deterioration in the upper 1-foot of soil increases with increasing stand age. An incomplete analysis of data from twenty-seven 1-acre plots in stands ranging in age from 20 to 160 years suggests that in the 1 to 10 mm. diameter classes of root abundance and length per square foot of basal area decrease in the upper 1 foot of soil as stand age increases. Apparently, normal rootlet mortality does not vary greatly in healthy white pine stands from one age class to another.

7. Thinning dense stands of white pine or eradicating pole-blighted stems from diseased stands have not proved beneficial in halting the progress of pole blight. In comparing thinned and unthinned plots, pole-blight occurrence and damage is 2½ times greater in thinned plots. Three years after the removal of all diseased stems in another series of plots, pole blight continues to appear in the residual stand with a resulting reduction of healthy white pine volume.

8. Distribution surveys of pole blight during 1955 were limited to examinations of healthy stands near to and south of the southern limits of the disease. A suspected area, closely resembling pole blight, was found in the Clearwater National Forest in Independence Gulch about 6 miles north of the Kelly Creek Ranger Station. This area is outside the known range of pole blight. During the course of field work on other projects three new pole-blight areas were confirmed within the known range of pole blight.

9. The field work on damage appraisal surveys in pole-blighted stands has been completed. Surveys were conducted in four major diseased stands in 1955 which gives a total of 16 stands that have been sampled throughout the range of pole blight. Eight of these major stands are in old centers of damage and 8 are in recent damage centers. In addition to the major stands, 17 small newly affected areas were sampled for damage. Data from 12 of the 16 major diseased stands have been analyzed. For the 12 stands an average of 56 percent of white pine basal area is either affected or dead from pole blight with a range of 35 to 77 percent.

COMANDRA BLISTER RUST IN LODGEPOLE PINE

The Comandra Blister Rust is a fungus native to North America. It is known to attack several species of pines, including lodgepole pine. There is no record in the literature of the rust causing damage to the latter. False toadflax (Comandra umbellata) is the only known alternate host plant of the pathogen in the region. It has no forage value for livestock and big game animals.

Heavily infected lodgepole pine stands are now known to be present on six national forests in Region 4. In one stand it was estimated that 98 percent of the trees were diseased; estimates made in some other stands range between 65 percent and 85 percent. In all affected stands there is ample evidence that the fungus is intensifying at a fairly rapid rate and that damage is increasing.

Lodgepole pine has long been known to be a very occasional host of the rust. All evidence shows that intensification of the fungus in the affected stands is of relatively recent origin, i.e., about 15 to 20 years ago. The present behavior of the pathogen appears to be attributable to an increase on range lands of the toadflax. It is a plant not found in timber stands or in a good cover of grasses and appears in the succession when other plants die out. Its habitat is dry ground and rocky soils which usually have a low water content. Evidently there is more habitat area favorable for toadflax growth and spread today than there was some years ago. Furthermore, every heavy lodgepole pine infection area known is in association with range lands that have had long and heavy use.

No effective control methods are known at present. Tests of a number of herbicides for possible eradication of the alternate host plant are now under way on the Teton National Forest. Further disease research is needed for a more complete knowledge of the behavior of the fungus, particularly as it applies to damage to the pine, and to work out practical control methods. Closely allied studies should be undertaken to appraise present economic losses and possible future impacts of the disease, and to determine the importance of the pathogen as a factor in the management of lodgepole pine.

OTHER

The occurrence and buildup of the western gall rust (Cronartium coleosporioides) on ponderosa pine in part of the Lolo National Forest in Montana was reported in the Plant Disease Reporter. Intensification of this pathogen during the past 15 to 20 years has resulted in recent mortality and severe damage in limited centers in ponderosa pine stands along the Clark Fork River on the Lolo National Forest.

A new disease of eastern white pine was investigated and recorded for the first time in a plantation in the Northern Rocky Mountain region. The new root-stain disease in eastern white pine is caused by a fungus tentatively identified as a species of Leptographium, which invades the root system of host species causing a dark chocolate-colored stain of the sapwood. The stain progresses up the roots, past the root collar, and up the stem. Cambial death follows the stain in the xylem. Eventually the translocation system of the tree is girdled at or near the root collar. Tree mortality is quite rapid, almost coinciding with leader growth reduction and crown discoloration. The disease is potentially important in the West since lodgepole pine is also susceptible to it. The susceptibility of other conifers has not been determined.

Information on tree diseases and suggestions for control when known were provided to many forest users by staff pathologists. Contacts with National Forest administrative personnel were frequent and are resulting in a better understanding of the diseases prevalent in the forests of the Intermountain area. Cooperative help was extended to the National Park Service, to other agencies, and to schools.

FOREST INSECT RESEARCH

During 1955 the Division of Forest Insect Research went through a period of reorganization. It acquired a new Division Chief at the start of the year following the retirement of J. C. Evenden on December 31. The resignation of one entomologist, the transfer of another, and an increase in working funds posed a problem of staffing which was solved very satisfactorily. The group of entomologists located for many years at Coeur d'Alene was moved to Missoula, Montana and two entomologists from Ogden were stationed at the Research Center at Boise, Idaho.

With workers now stationed at Missoula, Boise, and Ogden, it is believed that problems of research, insect surveys, and technical advice on control projects in the Intermountain region can be handled much more effectively than before. In addition to the problems of staffing and relocation of field workers, a program of problem analyses has been under way to insure maximum use of personnel on the most important insect problems of the area. Active cooperation with all land managing agencies, Federal, state, and private, so essential to the program of the Division, has been strengthened during the year.

RESEARCH

It was realized that a thorough review of research needs in the area and the planning of future programs would require considerable time. Plans for 1955, therefore, were designed to carry on projects that had been under way for varying periods of time, while needs for change and new research were being considered. The majority of the research was performed at the Missoula laboratory, a good beginning was made on a research program at Boise for the southern Idaho area, and research was started in the Utah area from the headquarters at Ogden.

Engelmann Spruce Beetle

A program of research was started in 1952 in Montana and northern Idaho when a serious outbreak of Engelmann spruce beetles developed. Primary emphasis was placed on research directed toward the development of facts that would aid in control of the infestation. This work was continued in 1955. Considerable data on the habits of the species under conditions in Montana and northern Idaho have been gathered during the past 3 years.

This 1955 season the major attacks in green trees and trap logs occurred during the last week in June. Spruce beetle emergence from caged bole sections was observed in some instances at air temperatures of 38° to 40° F., but attacks occurred in green trees and logs during beetle flights when air temperatures rose to 70° F. It appeared that

a very small portion of spruce beetle broods at higher altitudes required 3 years for complete development. The amount of woodpecker work on infested trees by the fall of 1955 was as great as might be expected in the spring of 1956 and this extensive feeding in the fall destroyed some parent adult beetles that normally might have escaped the feeding, and also destroyed young larval stages. The accelerated rate of woodpecker feeding may be important in reducing the epidemic. Attempts were made to measure the effectiveness of trap logs in connection with logging of infested trees as a means of control but results are not clear-cut. Measurement of their effectiveness is complex and difficult.

Inasmuch as the epidemic appears to be decreasing in intensity rather rapidly, it is planned that accumulated data be analyzed and a determination made of needs for future research on the species.

Tree Classification Based on Susceptibility to Pine Beetles

Plots were established in 1950 to test the effectiveness of the ponderosa pine risk rating system as a measurement of the relative susceptibility of ponderosa pine to attack by the western pine beetle in the northern Rocky Mountain region. The periodic pine tree mortality cruise on the study plots is scheduled for 1956.

Selective Logging to Control Pine Beetles

The work on this project is scheduled biannually on even numbered years.

Douglas-Fir Beetle

One of the program changes agreed upon during 1955 was that of centering the research on the Douglas-fir beetle at the Boise Research Center. The Missoula laboratory had conducted research on some phases during the past years. This material has been turned over to Boise. This season a survey of the Douglas-fir beetle situation was made in southern Idaho. Based on fairly complete knowledge of the area it will be possible to set up suitable study areas. Location of loss groups was provided by aerial observations and measurement of the diameters and numbers of Douglas-fir trees killed by the beetle in 1954 and 1955 was recorded. At the same time, possible causes of the damage were sought by observations. Such factors as logging, windthrow, and fire are easily recognized but were not present in the neighborhood of most loss groups. It was noted, however, that a great proportion of damage was located well up the sides of mountains and ridges. Information was gathered concerning the life of local outbreaks. It was noted during measurement of loss groups that most of the mortality had occurred rather recently. Current loss was searched for in a 2½-chain corridor adjacent to faded groups and it was often found that such loss was not present or only in reduced amounts. This situation needs exploring more fully to determine whether the beetles fly away from

the groups or whether brood mortality accounts for the loss reduction. Collections of infested material were made to obtain information on natural enemies. Preliminary investigation of the possible interrelationship of spruce budworm damage and Douglas-fir beetle damage revealed that approximately 90 percent of the beetle-caused damage occurs in areas free of appreciable budworm damage at the present time. Based on the preliminary investigations this season, a work plan for 1956 is being developed.

Spruce Budworm

During the past few years limited studies on the biology of the spruce budworm have been carried on. During 1955 it was determined that a major study was needed and initial steps were taken to develop a problem analysis and work program. A review of literature was made. Entomologists at the PNW Station were consulted on biological techniques, progress of their studies, and suggested lines of study in the Intermountain region. Experimental plots previously established cooperatively with Potlatch Forests Inc., were reactivated.

Scattered field observations showed natural control possibilities. A parasitic fly, *Pseudosarcophaga affinis*, was abundant in several areas.

It is planned to complete the problem analysis and prepare work plans so the program can start in earnest in 1956.

Black Hills Beetle

Limited studies of the Black Hills beetle were conducted in southern Utah. The seasonal cycle of the beetle in this southern section of the area differs from that encountered in the more northern ponderosa pine areas. Cages were placed on infested trees to determine the seasonal emergence pattern. Comparisons made to determine if there were significant differences in the pattern because of elevational and exposure differences showed the variation between cages to be slight. There appeared to be substantially greater emergence from infested trees in the areas where the epidemic conditions had most recently developed. In closely controlled research experiments it appeared that an emulsion of ethylene dibromide containing 1½ pounds of EDB per 5 gallons of final mix would be satisfactory to control the Black Hills beetle. This is one-half of the strength ordinarily used. However, when used under conditions of application by control project personnel, the results were somewhat erratic. This is substantially in agreement with past experience; allowances must be made for less careful application in large-scale operations by less experienced personnel.

Puto sp.

A spruoe mealybug (Puto sp.) has been known in the Engelmann spruce stands of southern Utah for some time. The infestation has spread and damage appears to be more severe than previously thought. A limited study in the area has been established to determine the extent of the infestation, significance of damage, and to gather such biological data as possible to determine if control might be desirable or possible. It was determined that about 60,000 acres of spruce are infested. Trees of all ages, including small reproduction, are affected and some quite severely. Biological data gathered to date indicate a possible 2-year cycle with both mature females and newly born young overwintering. Females are active on twigs from June until August when they return to the boles and hide under bark flakes. Living young were being produced by mature females in September. Stem analysis of infested trees indicate the heaviest concentration of mealybugs is at midbole. Future observations will determine more biological facts about the species including presence or absence of biological control factors.

White Fir Needle Miner

Defoliation by Epinotia meritana Hein., the white fir needle miner has been heavy in parts of Bryce Canyon National Park for some time. Damage along scenic highways in the Park and in adjoining commercial timber has been increasing. Results of trial and error tests in past years to control the species have been very erratic. This year a cooperative study with the National Park Service was started. It was felt that more should be known about the seasonal development of the insect in order to develop satisfactory control methods. An assistant employed by the National Park Service, following the plan developed cooperatively, made observations and oollections during the season whereby the seasonal history of the species was determined. Data were collected on the degree of defoliation, needle miner population, and the number of needles mined per larva. Weekly collections of specimens were preserved for disseotion to determine the presence of parasites. Limited tests with small hand equipment were performed using DDT, Dieldrin, Malathion, and Julius Hyman 269 formulations. Data have not been analyzed but it appears that DDT and Malathion may have promise.

Improvement of Inseot Survey Methods

Research to improve both aerial and ground insect surveys has been strengthened. The needs for improvement are present in both detection and appraisal surveys. Field tests were made to develop more efficient airplane flight patterns to obtain better detection of current infestation symptoms and better ooverage of forested areas. Descriptions of tree damage symptoms often confused with symptoms of insect damage are being prepared to aid aerial observers in classifying insect injury. Improvements were made and tested on aerial survey mapping facilities.

Tests were made to obtain beetle brood density measurements as a measure of the severity of infestations. It is believed that research into brood intensity and change can be utilized to increase value of appraisal surveys. Similar tests were started on spruce budworm.

It is planned to continue and expand these activities. A manual is being prepared on detection surveys for use by cooperators.

Cooperative Study - Boise Basin

A study by the Division of Timber Management of cutting methods at the Boise Basin Experimental Forest includes determination of mortality in the reserve stands. The Division of Forest Insect Research is cooperating. This season there was little activity on the part of the entomologists. A review is being made and upon agreement the cooperative features will be described and made part of the work plan to insure continuity.

INSECT SURVEYS

The Division of Forest Insect Research is responsible for detection and appraisal insect surveys. Increased detection survey coverage depends upon participation by cooperators in all land managing agencies, state services, and interested industrial and private land managers and owners. The past year has seen increased interest and participation in the insect survey program.

In the Intermountain region during the past season detection survey coverage has increased. In the northern portion of the region, over 18 million acres of forested land was surveyed by air and ground work and over 4 million acres of infestation by various insects was recorded. Most of the damage is being done by spruce budworm. In the southern portion of the region it is estimated that 15 million acres of forested land were surveyed by air and ground. The spruce budworm infestation of 547,000 acres in southern Idaho represents the greatest acreage of infestation this year.

Special mention might be made of new situations discovered during the season. On the Bridger Forest in western Wyoming a rather serious outbreak of Engelmann spruce beetle was revealed by aerial surveys. Prompt action by Timber Management in Region 4 has resulted in the sale of timber in the area. Logging of infested timber plus a limited trapping program is scheduled.

A total of 44,100 acres of Douglas-fir tussock moth epidemic infestation in eastern Washington and Idaho was revealed by surveys. An examination of the infestation by research personnel has revealed a rather high degree of biological control and while plans are being formulated for chemical control it may be that analysis of data will

show that it may not be needed. This is an example of need for increased attention to appraisals and close correlation with research.

Appraisal of the Engelmann spruce beetle outbreak in Montana and northern Idaho shows a decreasing intensity of infestation. Using 1952 as an index of 1.0, the trend in 1953 was 1.9, in 1954 was 1.6, and in 1955, 0.7.

A new outbreak of mountain pine beetle was discovered on the Teton National Forest. While it is not extensive, the concentration of infestation indicates that control is advisable.

An infestation of an undetermined defoliator was found on western larch over 33,000 acres in several forests in Region 1, 14,000 acres of lodgepole pine were defoliated by blackheaded budworm and lodgepole pine sawfly in Yellowstone National Park, and 3,400 acres of lodgepole were found to be infested by a needle miner in Montana.

TECHNICAL ADVICE ON CONTROL

The Division furnishes technical advice to all land managers and owners on insect control projects. The year 1955 was notable for the demands for this service in the Intermountain area. The entomologists assisted in planning control projects, recommended methods, materials, and timing, assisted in training project personnel, inspected operations, and judged results of projects.

The aerial spray projects in Idaho and Montana against the spruce budworm required the greatest effort. Nearly 1,200,000 acres were sprayed during July. The combined logging and trap tree program to control the outbreak of Engelmann spruce beetles in Montana and northern Idaho continued. The direct chemical control program against the Black Hills beetle on the Dixie National Forest and Bryce Canyon National Park was again active in 1955. Several minor control projects required technical services.

In addition to services on active control projects, entomologists participated in precontrol planning in the case of a combined logging and trap tree project on the Bridger National Forest where a serious outbreak of Engelmann spruce beetle was discovered in 1955. Activity will start early in 1956. An upsurge of Douglas-fir tussock moth in eastern Washington and northern Idaho resulted in planning for control in case biological observations being made indicate needs.

FOREST FIRE RESEARCH

The year 1955 was one of challenge, opportunity, and progress for forest fire research.

In parts of the West, hot, dry weather, searing winds, and a series of lightning storms combined to produce a critical fire situation. Seldom has it been more evident that protection of western forests must depend primarily upon the technical advancement of fire control science. The measures required to either prevent or control mass fire situations call for the best that science can produce. The 1955 fire season showed that measures not yet known or developed are needed for adequate protection of forest, range, and watershed resources, or in some cases, for the safeguarding of human lives. This is the challenge to fire research.

The year 1955 produced opportunity for fire research. Increased efforts on the part of cooperating agencies provided a greater opportunity to speed up work on existing projects and to tackle new problems. Activity by cooperating agencies in the fire-research program is at an all-time high.

Progress was made on three major research projects--fire-danger-rating, logging slash, and Project Skyfire. In each of these fields of work a major publication was issued in 1955. More important, 1955 saw the development for field use in fire-control operations of equipment and techniques which are products of these research projects.

FOREST FIRE LABORATORY

The forest fire laboratory organized at Missoula last year was developed further in 1955 mainly through the efforts of cooperating agencies. Donald Fuquay, research meteorologist of the Munitalp Foundation, was assigned to the laboratory staff on a full-time basis. DeVer Colson, research meteorologist of the Washington office of the Weather Bureau, was assigned to the laboratory for duty during the fire season. At the end of the year, plans were being made for the development of laboratory facilities needed in atmospheric, instrument, electronic, and fuel research in conjunction with the fire-danger-rating, logging slash, and lightning fire projects. These plans call for the temporary development of the most urgently needed facilities as a stopgap measure which will permit some progress in 1956 and the later development of more adequate laboratory facilities which are needed to insure continued progress.

The field arm of the laboratory is maintained at the Priest River Experimental Forest. These facilities received intensive use during 1955 on the fire-danger-rating, logging slash, and lightning fire projects. Priest River was the fire season headquarters for three scientists of the Munitalp Foundation and part time headquarters for all members of the Division of Fire Research. Others using the Priest River laboratory in 1955 included research workers from the University of Idaho, the University of Washington, and the U. S. Weather Bureau. Investigations have been started on the possible installation of research radar facilities at Gisborne Mountain lookout for use in Project Skyfire.

FIRE-DANGER RATING

Burning-Index Rating System

The year 1955 marked the development of a new and improved system of rating burning-index in Intermountain forests. The new system was adopted by forest protection agencies in Montana, Idaho, western Wyoming, northeastern Washington, Utah, and Nevada. The system is based on the following:

Mountaintop and Valley Bottom Fire-Danger Stations measure fuel moisture, wind velocity, relative humidity, temperature, precipitation, and lightning occurrence. These paired stations sample fire weather at two critical points in mountainous country. Burning-index between these two points is computed with a conversion table on the burning-index meter.

Model 8 burning-index meter evaluates four key fire-weather factors into one numerical scale.

Standard forms are used for recording fire-weather factors at all stations, for computing today's and tomorrow's burning-index and for plotting day-to-day changes in burning index. Lightning occurrence is also plotted at each station. These standard forms enable all agencies to gather and use comparable data, and are an aid in fire-danger-rating research. Records from some 300 fire-danger-rating stations now come to the Forest Fire Laboratory at Missoula.

Fire Behavior Evaluation Guides used in conjunction with burning-index ratings permit estimates of fire rate-of-spread according to variations in fuel types, topography, and time of day.

The new system of burning-index rating was featured at a fire weather training school conducted at the Missoula Smokejumper Center by the staff of the Forest Fire Laboratory and the Missoula and Boise fire-weather districts of the Weather Bureau. This training school

was attended by personnel of forest protection agencies in Idaho, Montana, northeastern Washington, and western Wyoming. In 1956 additional training will be conducted for personnel in Utah and Nevada.

Model 8 Burning-Index Meter

The Intermountain Model 8 burning-index meter is the result of some 20 years of research. It is a direct product of the Model 7 meter which was given extensive field tests in 1954. As a result of these tests, a new model has been produced which is more sensitive to the wide range of fire-weather conditions of the Intermountain West than any meter heretofore used. The Model 8 burning-index meter has these features:

Severity index, or the cumulative effects of past weather, is evaluated from the 5-day total of fuel moisture as measured by 1/2-inch fuel moisture sticks. The 5-day 1/2-inch stick moisture provides an evaluation similar to that which can be obtained from measurement of the moisture content of large logs. The resulting severity index rating is an indication of the trend of the fire season. Day-to-day charting of severity index gives a numerical rating to the effect of drought or of many days of drying weather, or conversely, of many days of cool, wet weather. The effect of past weather is constantly brought up to date by the severity index system.

Current burning-index is computed by incorporating today's fuel moisture, relative humidity, and wind velocity with severity index. The Model 8 burning-index meter is thus sensitive to both past and immediate effects of key fire-weather factors. Given a low severity index and a high current burning-index, the result is only moderate fire danger. The combination of high severity index and high current burning-index would indicate a much more severe fire-danger situation.

The scale on the Model 8 meter has been designed so that interpretations may be described as follows:

Burning-Index	Fire Danger
1 - 20	Low
21 - 35	Moderate
36 - 50	Average
51 - 70	High
71 - 100	Extreme

Burning-index conversions from one time and place to another are computed by a slide rule device on the back of the meter. The conversion system is the result of extensive research of the hour-to-hour

and day-to-day variations of burning-index factors on mountain slopes. Burning-index conversions can be made from valley bottom or mountain-top weather stations to north or south exposures on the lower third, the middle third, or upper third of mountain slopes. Under settled weather conditions, burning-index may be estimated for up to 8 hours from the time of measurement. Conversions of this type enable fire dispatchers and fire bosses to make reliable estimates of burning conditions at the site of a fire. They are also useful to forest managers in planning slash disposal and prescribed burning operations.

Burning-index predictions for tomorrow are computed on the basis of today's rating, tomorrow's weather forecast, and local experience in the trends of fire weather. The Model 8 meter contains a guide for estimating tomorrow's burning-index.

Large Log Study

Study of the moisture content of large logs exposed in various manners at the Priest River field laboratory continues to yield valuable information. Large logs may be visualized as a unique analog-computer capable of integrating the long range effects of drought and sunshine, precipitation and temperature, late spring and early fall, and many other factors of forest-fire danger. Analysis of large log moisture in relation to other factors has shown that general trends can be closely approximated by the 5-day totals of 1/2-inch fuel stick moisture. This discovery was a key factor in the development of the severity index rating used in the Model 8 burning-index meter. General results of the large log study were summarized in a paper entitled "How large dead forest fuels dry" which was presented by Charles E. Hardy at the annual meeting of the Northwest Scientific Association.

Fire-Danger-Rating Equipment

In the servicewide fire-danger-rating equipment development project under way at the Forest Fire Laboratory, the following progress was made in 1955:

A simple battery-powered wind counter was developed, field tested, and is ready for production. This wind counter records velocity in miles per hour over any given period. It enables average afternoon wind velocity, an important factor in fire-danger measurement, to be computed accurately. The instrument may be used in conjunction with any standard 60th mile contact anemometer.

A battery-powered fan psychrometer was designed and given preliminary field tests. This instrument should meet the need for a low-cost, reasonably accurate, device for measuring relative humidity at field stations.

A portable fire-danger station was designed and given preliminary field tests. The purpose of this station is to provide a lightweight fully portable unit for use on going fires, slash burning jobs, and other sites where temporary measurement of fire-weather factors is desirable. The present model weighs about 25 pounds and is compact for easy back packing. An alternate model will be designed for dropping by parachute from aircraft. The complete portable fire-danger station includes a lightweight shelter attached to pack board, a collapsible aluminum anemometer pole, an anemometer, a battery-powered wind counter and psychrometer, a rain gauge, maximum-minimum thermometers, fuel moisture sticks and scales, and a burning-index meter.

Two models of lightweight, aluminum instrument shelters were designed and given preliminary field tests. The purpose of these instrument shelters is to provide prefabricated knockdown units for use at lookout stations and other field locations where weather factors are measured only during spring, summer, or fall months, and then the instruments and shelter are removed for protection from severe winter weather. A key factor in the development of these lightweight knockdown shelters is the testing of aluminum as a suitable material for instrument housing. Preliminary tests of the heat reflection and absorption characteristics indicate that aluminum is a satisfactory material for shelters.

Recording Fire-Danger Station

Preliminary investigations were made of the possibility of developing a fire-danger station which would automatically record fuel moisture, wind velocity, and relative humidity. Such a station is needed at remote locations where weather measurement is important and manpower is limited. Development of a suitable fuel moisture recorder is the main technical problem in this project.

Fire-Danger Rating Operations

An 84-page illustrated publication, "Fire-weather and fire-danger station handbook" by Charles E. Hardy, Charles E. Syverson, and John H. Dieterich was issued. This handbook is a joint publication of the Weather Bureau and the Intermountain Station. It is now the standard guide for fire-weather and fire-danger station operations in the Intermountain West.

During 1955 the Forest Fire Laboratory continued to give technical assistance to forest protection agencies in the development of networks of fire-danger rating stations. In conjunction with the Weather Bureau, assistance was given in the training of personnel, and in the inspection of stations. An arrangement was developed this year for coordinated inspections by personnel of the Boise and

Missoula fire-weather districts and the Forest Fire Laboratory. Special attention was given to fire-weather and fire-danger rating problems in Utah, Nevada, and eastern Montana. The Bureau of Land Management, National Park Service, Indian Service, and Forest Service participated in the program.

Technical supervision was given to the manufacture of 2,200 sets of fuel moisture sticks at the Forest Service Spokane warehouse. Performance tests of these fuel moisture sticks were conducted at the Priest River field laboratory. Technical supervision also was given to the repair and calibration of fire-weather instruments received from all agencies. This work was performed at the Missoula Aerial Fire Depot. Wind tunnel tests of anemometers were made at the Forest Fire Laborabory.

PROJECT SKYFIRE

Project Skyfire is a broad cooperative program of lightning fire research aimed at (1) gaining basic information on lightning fires and storms, and (2) testing the possibilities of preventing or reducing the severity of lightning fires through cloud modification. The Munitalp Foundation, Inc., and the Intermountain Station are the principal backers of Project Skyfire. Dr. Vincent J. Schaefer, Director of Research for the Munitalp Foundation, Inc., is Co-Director of Project Skyfire. The United States Weather Bureau, the Universities of Washington, Idaho, and Montana, the Boeing Airplane Company, the General Electric Research Laboratory, the National Park Service, the California State Division of Forestry, Meteorology Research, Inc., the California Forest and Range Experiment Station, and the western regions of the Forest Service, all play important roles in the research program. Project Skyfire involves lightning fire research throughout the Western United States.

Cloud and Lightning Survey

The cloud and lightning survey was continued from a network of lookout stations in Wyoming, Montana, Idaho, Washington, Oregon, and California. Each day during the fire season the observers at these stations record the development, movement, and action of cumulus clouds, middle level clouds, and upper level clouds. At intervals during the day they measure cloud heights and speeds. When lightning occurs they attempt to count the number of strikes and map the area covered by the storm. Each day the observers transmit a special radio report giving a capsule summary of the cloud and lightning situation to the Skyfire staff at Priest River and Missoula. Later, when full reports are received from the lookouts by the Forest Fire Laboratory comprehensive regional cloud and lightning maps are

prepared for each day of the fire season. These techniques are providing life cycle information on lightning storms which is needed in the development of lightning fire prevention and control programs.

Cloud measurement was made more accurate during 1955 through the development of a cloud theodolite. This instrument, fabricated from an aircraft compass and a gunsight, can be used as an aid in measuring cloud height, direction of movement, and cloud speeds. It is especially useful for estimating the speed of movement of high level clouds. A combination of cloud identification at upper and middle levels and cloud velocity measurements provides a means of tracking the jet stream in the survey network. The cloud theodolites were mounted on the catwalks of all Skyfire lookout stations during 1955.

A publication, "Project Skyfire cloud and lightning observation handbook" by Paul B. MacCready, Jr., Vincent J. Schaefer, John H. Dieterich, and J. S. Barrows was issued in 1955. This handbook is a general guide for all cloud and lightning survey activities. It outlines a system of cloud identification which is now in general use at many forest stations in addition to the Skyfire stations.

Time-lapse cloud photography with the special outfits provided by the Munitalp Foundation was continued at selected lookout stations. Tests were also made with special stereo cameras and a stereo analyzer to obtain quantitative data on cloud dimensions.

Lightning Storm Analysis

A major objective of Project Skyfire is to better understand lightning storm characteristics and to be able to identify the differences between storms. Key questions in this field include: Why are some storms dry and others wet? Why do some storms start few fires and others many fires? Why do some storms move slowly and others very fast? Can lightning storm types be predicted accurately? Can lightning storm types be recognized from cloud surveys?

In 1955 the Washington office of the Weather Bureau assigned research meteorologist DeVer Colson to Project Skyfire to assist in the lightning storm analysis program. Throughout the 1955 fire season Colson worked closely with Missoula fire-weather forecaster W. R. Krumm and members of the Skyfire staff on methods of identifying the basic characteristics of each storm. It is too early in the program to report conclusive results. However, preliminary observations indicate that there are at least three major storm types in the project area which are classified as air mass or local orographic type storms, frontal storms, and high level storms. The effect and location of the jet stream in relation to these storms is being studied.

Special Forecasts

Weather forecasting is an important factor in Project Skyfire. Daily weather forecasts including special analysis of the lightning situation are provided by W. R. Krumm, fire-weather forecaster of the U. S. Weather Bureau at Missoula. In addition, the Missoula fire-weather staff provides the Forest Fire Laboratory with daily maps of the jet stream, and with much other basic meteorological information. The flow of information works both ways. Reports from all Skyfire stations are transmitted by radio daily to the Missoula fire-weather office.

During 1955 the Severe Storm Forecasting Center of the Weather Bureau at Kansas City provided daily special forecasts and analyses for the Skyfire staff. These special forecasts concentrated on the jet stream and on instability patterns. They were watched especially closely in relation to fast-moving, high level lightning storms. The forecasts were found to be quite accurate and of great help to the Skyfire staff.

Long range forecasting is an important factor in lightning fire control. Under arrangements made by the Munitalp Foundation, Mr. Raymond Falconer of the General Electric Research Laboratory issued experimental long range forecasts for the 1955 fire season. The long range forecasting system developed by Falconer predicts temperature and precipitation 39 days in advance. These forecasts were issued weekly. They indicate the weather for each day of the forecast period. The science of long range forecasting involves many difficulties and unknowns and conclusive results are not yet available. This year the precipitation forecasts were 75 percent correct in July, 71 percent correct in August, and 72 percent correct in September.

Atmospheric Laboratory and Instrumentation

The mobile atmospheric research laboratory operated cooperatively by the Munitalp Foundation, the University of Washington, and the Forest Service was used in field studies throughout the 1955 fire season. At Priest River the laboratory made several 24-hour continuous runs measuring micrometeorological factors associated with lightning storms and with fire-climate on mountain slopes. The laboratory also provided data for use in conjunction with silver iodide generator tests at Missoula and Priest River.

Dr. Vincent J. Schaefer and Donald M. Fuquay of the Munitalp Foundation, developed a technique for use of the laboratory while in motion on mountain roads. Tests made on Gisborne Mountain at the Priest River Experimental Forest showed that the moving laboratory could be used to detect the presence of silver iodide

concentrations at various positions on mountain slopes, and at various times. This is an important development which may be of assistance in the evaluation of cloud-seeding experiments in lightning prevention.

Development of instruments is an important phase of Project Skyfire. Late in 1955 preliminary work was started on the development of a lightning counter for use at lookout stations. This will be an electronic instrument which records each lightning stroke within a given distance of the observing station. The instrument will fill a vital need in lightning storm analysis. Preliminary studies show that such an instrument can be developed at rather low cost. Principal bottleneck in the development program is lack of suitable laboratory facilities and instruments for testing and calibration of the unit.

Investigations are being made on the possible use of radar as an aid in lightning storm tracking and analysis. Available information indicates that radar can be a very important tool in lightning fire research, and that eventually radar may become part of the standard equipment at a few key lookout stations. The Project Skyfire staff are looking into possible cooperative arrangements for radar with the Air Defense Command and with the Weather Bureau. A modified radar especially designed for lightning detection is most desirable and would probably produce the best results.

Experimental Meteorology

A key question in cloud-seeding operations of the type which might be used in lightning reduction, is the feasibility of using silver iodide ground generators. Under the auspices of the Advisory Committee on Weather Control a series of experiments aimed at this question were performed in the Missoula vicinity. These experiments were carried out by Meteorology Research, Inc., of Pasadena, California, under the direction of Dr. Paul B. MacCready, Jr., and with the assistance of the Forest Service and the Munitalp Foundation. The base of operations was the Smokejumper Center at Missoula. The experiments involved the use of a glider equipped with a portable cold box to collect and test air samples over an area where silver iodide generators were operating. This is an important new technique for determining the location and the effectiveness of silver iodide nuclei. The glider provides an excellent means of collecting air samples because it climbs in the same thermals where silver iodide is likely to be found, and the glider does not introduce exhaust fumes into the sample. The glider is towed from the airfield with a power plane and then cut loose.

The tests showed that silver iodide crystals were found up to 4,000 feet above the generators and up to a maximum horizontal distance of 15 miles. With the type of generators used it is concluded that satisfactory concentrations of silver iodide nuclei will reach clouds in the summer months.

Program Review

Under arrangements made by the Munitalp Foundation, Dr. Herbert Riehl, of the University of Chicago, visited Project Skyfire field operations for the purpose of reviewing the entire research program and of making recommendations for future activities. Dr. Riehl was given a general briefing of the entire program and visited several field stations and the Forest Fire Laboratory. Upon conclusion of his visit he prepared a report setting forth many helpful suggestions for future research.

Advisory Committee on Weather Control

Captain H. T. Orville, Chairman of the President's Advisory Committee on Weather Control, and nine members of the committee reviewed Project Skyfire field operations during the 1955 fire season. The committee examined Skyfire activities as one phase of their over-all job of making recommendations for a national policy and program on weather control research and operations. Lightning fire prevention and control is an important segment of the national problem.

LOGGING SLASH RESEARCH

Logging slash research is carried out in cooperation with several state, private, and Federal agencies. Principal contributor to the project, along with the Intermountain Station, is the Forest, Wildlife, and Range Experiment Station of the College of Forestry, University of Idaho. Also assisting in the project are the University of Washington, the Munitalp Foundation, the California Forest and Range Experiment Station, and National Forest Administration. In 1955 a major progress report, "Logging slash--A study of the problem in Inland Empire Forests," by D. S. Olson and George R. Fahnestock, was issued as Bulletin No. 1 of the University of Idaho.

Experimental Burning

During 1955 the first major phase of the experimental burning program to study slash flammability was completed. Collections of slash of the nine commercially important tree species of the northern Rocky Mountains have been burned both during the year of cutting and 1 year after cutting. During the period 1952-1955, 173 plots of lopped slash and 48 plots of chipped slash have been burned. Rate-of-spread records have been kept on each plot, and heat radiation records on all of the lopped slash plots with a very few exceptions. The stage is set for detailed analysis of all results obtained thus far.

In late August and September 63 plots were recharged with lopped slash of all nine species at the three weights per acre used throughout the experiments. Burning will be carried on again in 1960 to determine the effect of aging 5 years on flammability. Interim records will be kept of compaction and apparent physical changes.

Near-perfect weather during August 1955 permitted expeditious burning of 60 plots. On 48 plots, 1-year-old slash of ponderosa pine, lodgepole pine, western larch, and grand fir was burned. As noted for the five other species, aging 1 year appeared to reduce fire rate of spread significantly. Fires in the two species of pine slash showed the least reduction of all the species in both rate of spread and heat intensity. To clear up the question of comparability of heat radiation data between years, on several plots radiation was measured simultaneously with the three radiometers (black-ball, Gier and Dunkle directional, and Beckman-Whitely flat-plate) used in the course of the study. Gasses were collected from the convection column of one fire to be analyzed as a check on the completeness of combustion. Dr. Konrad Buettner, of the University of Washington, gave valuable service in the determination of fire temperature, radiation intensity, and heat budget.

The other 12 plots were holdovers of 3-year-old western white pine, western redcedar, Douglas-fir, and western hemlock slash which early rains had prevented burning in 1953. Records from these plots will provide information on the effect of age between the first and the fifth year after cutting.

Slash Measurement

Weight per acre.--Results of experimental burning show that quantity, expressed as tons per acre, dry weight, is the critical factor affecting flammability of the current year's slash. Our own studies and those of the California Forest and Range Experiment Station have developed a method of calculating crown weight, hence, expected weight of slash, for individual trees from measurements of d.b.h. and crown length. In 1955 a start was made on putting weight calculations on an acre basis. Detailed crown measurements and descriptions were recorded for every tree on one 1/2-acre permanent sample plot. Crown lengths of representative trees were measured on additional plots. Summation of the calculated weights of all tree crowns on a plot will provide the best available approximation of potential slash weight per unit of area. Thus a start has been made toward ultimate preparation of slash "yield tables" which will show with acceptable accuracy the weight per acre of slash per thousand board feet that can be expected to result from cutting in each forest type as modified by age, site, and stand density. This knowledge will make possible realistic appraisal of the expected slash disposal job on any area before the timber is cut.

Classification and Measurement of Slash Components.--Compactness and surface-area-to-volume ratio are two important factors affecting combustion rate. Annual measurement of slash depth on the experimental burning plots is providing information on compactness in relation to species, age, and weight per acre. Some information on the area-to-volume ratio has been obtained by determining the weight, and calculating the volume and surface area of material of different diameter classes in branches of several species. For the few branches that were dissected, needles were found to comprise roughly 20 to 50 percent of the total ovendry weight, the percentage increasing in proportion to the tolerance of the species. Douglas-fir, on which the most complete analysis was made, had 35 percent of its weight and 80 percent of its surface area in needles. The approximate surface area per pound of Douglas-fir slash was found to be 25 square feet.

The value of classifying and measuring slash components includes many possible applications in forest management and protection. One use in the field of fire control is to establish comparability of different fuels on a measured or mathematical basis. Branch analysis carried on in conjunction with experimental burning of the same type of material should lead to a much better understanding of rate-of-spread and radiation differences. To provide more certain information and permit better evaluation of possible uses, additional branches were collected in the fall of 1955 for subsequent analysis.

Slash Disposal Methods

Partly as a result of encouragement by the Station, the St. Joe National Forest bought a portable chipper in 1955. Preliminary arrangements have been made for a cooperative study of comparative costs and accomplishments of disposal by chipping and by hand piling and burning.

ALASKA FIRE RESEARCH

In September, at the invitation of the Bureau of Land Management, Jack Barrows visited Alaska for the purpose of investigating the fire control problem in the interior forests and fire research needs. Working in cooperation with Bureau of Land Management foresters, Barrows paid special attention to the requirements for early development of a fire-danger rating system. Technical assistance will be given to the Bureau of Land Management in the development of a few key fire-danger stations and experimental use of the Intermountain burning-index rating system. Interior Alaska has some 225 million acres requiring fire protection. Lightning and man-caused fires are causing an annual burn varying from 1-1/2 to 4-1/2 million acres. The territory provides a virgin opportunity for fire research and the technical advancement of fire control.

NATIONAL FIRE RESEARCH CONFERENCE

The Intermountain Station was host to a national fire research conference held at the Missoula Smokejumper Center, October 24-28. Attendance included all of the professional fire research technicians of the Forest Service, two station directors, several regional fire chiefs, equipment development technicians, and three members of the Weather Bureau. This was the first national fire research conference since the meeting held at Priest River in December 1941.

FOREST ECONOMICS RESEARCH

The Division of Forest Economics Research has been assigned reponsibility for the forest survey and economic studies in the 9 Mountain States: Montana, Idaho, Nevada, Utah, New Mexico, Arizona, Colorado, Wyoming, and South Dakota. The past year has been spent largely in replanning our program to fit this enlarged area.

FOREST SURVEY

Survey Plans and Techniques

A tentative plan for the forest inventory of the Rocky Mountain States was prepared early in 1949. Because of the many changes taking place during the past 6 years it has become necessary to revise this original plan. Work on the revision was started this year. Information gathered in connection with the recent Timber Resource Review gives a much better basis on which to plan than was available in 1949. As a further aid in preparing an up-to-date plan a critical look was taken at methods of making sample surveys. Four different sampling techniques for determining forest area were studied. These included line sampling, block sampling, strip sampling, and dot sampling. Aerial photographs were basic to all of these. To round out the story, strip sampling without photographs was also studied. Cost per acre of commercial forest land varied from 0.80 cent to 1.26 cents assuming that suitable aerial photos are available and only prints need be purchased. When new photography must be taken the costs varied from 2.23 cents to 2.72 cents per commercial forest land acre. The difference in cost for the different methods is not great, so major consideration can be given to the needs of the customer and amount of cooperation available when selecting the method to use.

To further improve our method of operation we made a complete conversion of the compilation phase to the International Business Machine system. A coding scheme was set up in cooperation with the California Forest and Range Experiment Station, and arrangements were completed whereby this station will provide us with the tabulations we need.

In cooperation with the California Station a brief test was made of the use of "mark sense" cards for recording inventory plot data in the field. As a result of this test we found that use of these cards required too much additional time on the plots; therefore we cannot use them on the Forest Survey. This system should be quite acceptable for use on plot inventories involving collection of less information than on the Forest Survey.

Aerial Photo Interpretation

During 1955 the program on photo interpretation research gained momentum with the initiation of several studies. These were concerned largely with questions of photo dot sampling in areas of rough terrain such as encountered in the Rocky Mountain area. Studies completed or under way include:

1. The relation of size of minimum area to the proportion of forest and sawtimber acreage obtained by dot sampling on aerial photos. This study is nearly complete.

2. Significance of image displacement and scale difference due to relief when sampling on aerial photographs. This study is in the compilation stage.

3. The accuracy of stand height measurements on aerial photos in the Rocky Mountains. This study has been completed and results have been published. Because height correlates well with volume, stand height is one of the most useful measurements foresters can make on aerial photos. The results of this study indicate that stand height measurements made on aerial photos compare very favorably with average stand heights derived from a few Abney readings made in the field. It is also pointed out that when corrections are made for elevation, height measurements made in areas of rough terrain are just as precise as those made in areas of more gentle terrain.

As a still further attempt to make fuller use of aerial photos we are working on the construction of aerial volume tables for conifers in the Rocky Mountains. Photo measurements have been completed for some 200 forest survey field plots. These photo measurements will be correlated with field-measured volumes to produce alignment charts giving average cubic- and board-foot volumes for various photo measurements.

An essential to successful use of aerial photos is well trained interpreters. After the interpreter is acquainted with the fundamentals he must become familiar with the terrain, cover, and species of the country in which he will be working. He is not always able to spend a lot of time in the field, so as an aid in training and making interpretations we have prepared 18 stereograms consisting of vertical aerial photos and horizontal ground stereo photos of conditions common to the White River and Arapaho forests of Colorado. Included with these stereograms are photo measurements of height, crown size, and stand density, and a narrative description of the stand. Also in connection with training, 12 basic problems in resource interpretation were designed along with interpretation aids to be used by the field crews.

Initial Inventory

Field work was concentrated in southern Idaho until August 1. About 1,712,000 acres of forest land were sampled. This brings the total forest area in south Idaho to 10,800,000 acres and completes the field phase of the survey job in this State. Compilation work was carried on throughout the season, and was concentrated at the California Station where the IBM installation is located. As of the end of the year about 80 percent of the total job was finished. A statistical report will be prepared and released during 1956.

Final plans were made for a cooperative survey with Region 2 of the Forest Service of a major portion of the commercial forest land in Colorado. Work has been started on photo interpretation for a complete cover map within the national forests. Field work in the spruce bark beetle-killed area was carried on by a 5-man crew during the summer. Contracts for new aerial photography for about 13,500 square miles were awarded by Region 2, in connection with this joint project. Some of this photography is being delivered now. Next year will see a concentration of field work in Colorado.

Maintenance Inventory

The maintenance survey was continued in Lincoln, Sanders, and Mineral Counties in western Montana. About 1,175,000 acres of forest land were sampled. Mineral County is now complete with minor portions of the other two counties left to do. Nearly 18 percent of the forest land in Montana has been reinventoried to date. If suitable aerial photography becomes available we should complete the field work in these three counties in 1956 and prepare a statistical report showing area of forest land and timber volumes.

Timber Cut

Early in 1955 a canvass was made of wood-using industries in Montana and Idaho to determine the amount of timber removed from the woods for the various wood products. The purpose of the data is to keep survey statistics up to date. Release of the information awaits correlation with Bureau of the Census data from its Census of Manufacturers in 1954. A publication will be issued early in 1956.

Our annual surveys of pole production in the northern Rocky Mountain region, and shipment of Christmas trees from Montana, were made. A survey to determine the pulpwood production in Idaho and Montana during 1954 was also made.

During 1954 Montana's Christmas tree shipments reached a record high. More than 3.4 million Christmas trees were shipped from the State. Flathead and Lincoln Counties continued as the leading producers. Missoula County made rapid strides towards overtaking the

leaders. Texas, Iowa, Missouri, and Oklahoma were the largest markets for Montana's trees, receiving nearly 42 percent of the trees shipped from the State.

Pulpwood production in north Idaho and Montana dropped about 87 thousand cords below 1952 production. This is 38 percent less than that year. Total production in Idaho and Montana was slightly more than 148 thousand cords. Pulpwood production increased in north Idaho and western Montana but the increase failed to compensate for a drop of more than 92 thousand cords in shipments from eastern Montana to mills in the Lake States.

The number of poles produced within the northern Rocky Mountain area in 1954 was 34 percent of total production during the peak year of 1947 and 67 percent of 1953 production. The following table shows the number of poles produced in 1954 by species and location:

Species	Montana	North Idaho	Northeast Washington	Total	Percent of total
Western redcedar	3,092	126,035	9,497	138,624	49.8
Lodgepole pine	101,842	0	0	101,842	36.6
Western larch	31,829	5,075	34	36,938	13.3
Douglas-fir	768	0	0	768	0.3
Total	137,531	131,110	9,531	278,172	
Percent	49.5	47.1	3.4		100.0

ECONOMIC STUDIES

As a first step in developing an economics research program for our enlarged territory we made a general analysis of the needs and opportunities for economic studies in the Mountain States. This analysis was published as a Station paper under the title, "Economics research needs related to wild land management and development in the Mountain States." In addition to suggesting types of economics studies which would facilitate management and development of the wild land resources in these states the report makes seven major points:

> Wild lands are geographically and economically dominant. Wild land resources are important in every region and no region can survive without them. Nevertheless, it is fair to say that the forests and rangelands of the Mountain States are closer to the life and welfare of the people in these states than is probably the case in any other region.

Other states have a direct and vital interest in the wild land management of the mountain region because this region supplies much of their water.

Much of the land is publicly owned; thus the public has an especially great responsibility for developing sound policies and programs for the use and management of wild land resources in the region.

The physical margins are narrow; thus the resilience of the Mountain States as an environment is low, and the land resource is particularly susceptible to damage from overuse or misuse.

The economic margins also are narrow insofar as return to the land is concerned.

Multiple use and integrated use are particularly urgent in the Mountain States.

We are still in the formative stages of resource development; so both the responsibility and opportunity for sound planning are doubly great.

During the year we undertook a study of the timber industry opportunities in the Idaho Falls, Idaho area and the Kemmerer-Green River, Wyoming area. This project was undertaken at the request of Region 4, Forest Service. That office and the 8 national forests involved have helped in various phases of the work. The study will be completed and a report issued in 1956.

Like the timber in many other parts of the Rocky Mountains, the stands tributary to Idaho Falls, Kemmerer, and Green River are underdeveloped. Some small sawmills, tie mills, and pole producers have cut from these forests for half a century or more, and during the past few years lodgepole pine from the Targhee National Forest has been shipped to pulp mills in Wisconsin. Nevertheless, all of these operations have utilized but part of the timber-growing capacity of the locality and in some cases they have not used it particularly well. Several factors have contributed to this situation: The economic isolation of the region marketwise, long hauling distances from woods to railroad, relatively low volumes per acre, rough topography, and the absence of "gold-plated" species such as white pine and ponderosa pine.

The recent growing interest of industries in Rocky Mountain timber has revived hopes of considerably greater development in this locality. There has been much discussion of the possibility of acquiring a pulp mill or two, medium size sawmills, and hardboard mills. The location here of any such plants would certainly be desirable from the standpoint of local employment. It would also open up new timber

supplies to the Nation and would round out the local economic picture. Expansion of the timber industries is likewise a must if there is to be good forest management in this area. Lack of markets for overmature timber which has suffered recurrent attacks from insects and diseases makes it difficult, and in a few cases futile, to protect the timber. Because of the inadequacies of the markets, utilization has been incomplete on many areas logged in the past. Residual tree growth that should have been removed has in some cases made it hard to regenerate new stands following logging or created other problems.

A careful analysis of the area and its probable opportunities will be especially helpful to new industries seeking to locate here. Furthermore, there is an unusual opportunity to develop the timber resource of this locality in a planwise manner because practically all of the timber is in the national forests and most of the development lies ahead.

The study has undertaken to answer five general questions:

1. How much timber industry can the forests of this area support?

2. How far is the timber industry likely to be able to go in utilizing the forest resource of the area?

3. What types of industrial development are most feasible and desirable in each of the areas?

4. Where should the industrial plants be located?

5. What present action will best facilitate any long-run objectives of timber industry development?

RELATED PROJECTS

During 1955 S. Blair Hutchison who has been participating in the over-all analysis phases of the Timber Resource Review for several years completed his assignment. He was co-author of Chapter VII of the Timber Resource Review, "Future timber supply and quality of domestic timber."

As a result of Harry W. Camp's assignment to Iran, Mr. Ziaedin M. Roshdieh of the Iranian Forest Service was assigned to the Station during the field season. Mr. Roshdieh was given practical training in forest survey techniques and consulted with members of the staff in regards to practices that could be applied to the forests of Iran.

Early in 1955 Mr. J. O. Lammi left the Station and joined the staff of the United Nations at Geneva, Switzerland as forest economist.

FOREST UTILIZATION RESEARCH

The activities of the Division of Forest Utilization Research were highlighted in 1955 by the retirement of I. V. Anderson, who completed 35 years of service, most of it in utilization work. The mid-year retirement of Anderson and delayed appointment of a successor has caused some interruptions in the program of activities in the division. There was no reduction, however, in the importance or urgency of this work.

Utilization research is an essential component in the complete development of forestry activities throughout the Intermountain and Rocky Mountain regions. As pressure for timber increases in the better established areas, and as development increases in the more remote areas, there is a constant need for research and guidance to timberland managers and forest industry operators. This is an era of technological change. New methods of logging and harvesting, new methods of log preparation, new methods of milling and manufacture, and new concepts of marketing are keeping the forest industries in a constantly changing situation. Only those industries which are willing and able to apply the most modern techniques find themselves in a truly sound position. The Division of Forest Utilization Research is charged with the dual responsibility of seeing that the research needs of the regional forest industries are met and that the results of the research are put into action with the minimum amount of delay. Some of the more important accomplishments along these lines are enumerated below.

TIMBER CONVERSION

It is estimated that as much as one-third of the remaining timber of the Intermountain and Rocky Mountain regions grows on steep mountainous slopes considered inaccessible or inoperable by many logging methods. As the demand for timber grows and as more of our forest lands are brought into operation, it is essential that these high altitude forests be made operable. Experiments in overhead cable logging on some of these mountain slopes has helped to demonstrate that these lands can be harvested in harmony with other mountain forest uses. Through the efforts of the division, a demonstration of a Swiss overhead cable logging system was installed at Turner Flats on the St. Joe River to log blister-rust infected western white pine from an overmature stand. Earlier logging in this same area had bypassed many of these steep sites where slopes run up to 165 percent. After nearly a year's operation the Swiss crew have demonstrated that these areas can be logged profitably.

Completion of earlier studies of the effect of time on the deterioration of bug-killed Engelmann spruce sawtimber showed that the yield of acceptable lumber was satisfactory and that there was only moderate degrade 2 years after mortality. Although some degrade and dollar loss was expected, it is significant that material which has fallen prey to the epidemic ravages of insects is still of a salvageable character. Information such as this makes it possible for forest land managers to continue and accelerate their harvest of dead material.

TIMBER GROWTH AND UTILIZATION RELATIONSHIPS

One of the prime considerations in growing timber is to grow it for a specific use. The ultimate goal, perhaps, in forest management is timber tailormade for a specific end-use. A cooperative study was undertaken with the objective of growing trees specifically for telephone and transmission poles. Western larch is a highly desirable species for this use and a study was established in which the growth rate, sapwood thickness, grain spirality, and other genetic factors as well as the effect of cultural measures will be studied in an effort to produce a maximum yield of the most desirable pole material in the minimum amount of time. This is only the first of such a series of studies that will be developed for a multitude of products.

PULP AND PAPER

It is an established fact that decay influences the amount of pulp yield from wood. Western hemlock, which grows rather abundantly in portions of the Inland Empire, is a desirable pulpwood species frequently left unused because of extensive decay. There has been a general reluctance on the part of pulpwood buyers to utilize this material for fear of low yields because of the high decay. A cooperative study has been undertaken to measure the influence of varying degrees of defect on the yield of hemlock pulp. Chips from logs of four degrees of decay will be pulped by various chemical and mechanical methods and the yields evaluated. The significance of the results of a study such as this is obvious. If it is found that at certain levels defect plays a less significant role than was previously anticipated, a considerable volume of western hemlock will find its way into pulpwood uses.

PHYSICS AND ENGINEERING

Telephone and transmission poles must be adequately seasoned to give satisfactory performance and to be properly treated with wood preservatives. Little is known about the seasoning characteristics of many of the commercial pole species. A study was undertaken this year to determine the air seasoning cycles for western larch poles. Information to date indicates that it takes so long to air-dry larch poles, especially of the larger sizes, that other means of seasoning should be explored. Perhaps the answer lies in a dry kiln of some design suitable for transmission and telephone poles.

Poles are an engineering material and their use follows specific design criteria. As part of a nationwide testing program conducted by the American Society of Testing Materials, western redcedar, lodgepole pine, and western larch poles were selected from the Rocky Mountain and Intermountain regions for strength evaluation. The results of this study are not yet published but indications are that strength values are comparable to the earlier estimates made in previous studies.

WOOD PRESERVATION

The natural durability of western larch has been studied, but a supplementary study of material from trees 160 to 200 years old was initiated to further document the information now available on natural durability. Since western larch is a thin sapwood tree when grown in many places, it is important to understand the natural durability of the heartwood.

PROGRAM ORIENTATION

These highlights of experiments and studies conducted during 1955 tend to illustrate the general activity and role of Forest Utilization Research of the Intermountain Station. There were, of course, many other contributions to the whole field of study, encompassing broader and more complete utilization of the forest resource. Accomplishments of industry, of forest management research, and of land management agencies in extending and broadening the usefulness of the various species, the more complete utilization of plant and woods residues, and the inauguration of new industries could be mentioned and discussed. Continuation of the general program and specific projects in the next year goes without saying.

As the result of the enlargement of the area of work of Forest Utilization, and the change in personnel, there may be some shifts in emphasis both as to geography and specific problems. There is an urgent need, for example, for work in southern Idaho and Utah in assisting operators, many of them newly established but with great ambitions, in getting the maximum benefits from their forest resources. There are definite indications that the feasibility and opportunities for pulp and paper development throughout the entire Intermountain region are reaching a new peak of attractiveness, and efforts must be made to familiarize possible operators and investors with the opportunities that exist. Intensive surveys to demonstrate and illustrate these pulp chances are under way. There is an ever-increasing need on the part of forest land managers, particularly National Forest Resource Management, to establish better and more objective criteria for the evaluation of logs for lumber, veneer, and other products.

As the competition for timber resources becomes increasingly more active and pointed it is essential that timberland appraisals become more definitive. Studies of this sort are scheduled and will be undertaken as the opportunities arise. There is increasing activity in the production of veneer and plywood from Intermountain and Rocky Mountain species. There is increasing activity in establishing and developing particle board operations following the ascending national trend in such products. There is always a great need for improvement and cost reduction in logging, log transportation, and log preparation.

Geographically, the work in Forest Utilization Research can be divided among the Inland Empire, the Northern Rocky Mountain area, and the Intermountain region. Emphasis in the past has been predominantly in the two northern areas, but the future will find increasing activity and opportunity in all three areas. Within the modest limitations of the existing unit, efforts will be made to serve all three areas with equal zeal.

BIG-GAME WINTER RANGE REVEGETATION

Planting Bitterbrush in Idaho

The big-game winter range revegetation studies conducted cooperatively with the Idaho Fish and Game Department on the Payette and Boise River drainages in southwestern Idaho are mainly concerned with planting techniques for bitterbrush.

Seeding depth.--A depth-of-seeding study showed that with an increase in seeding depth--which may be desirable in that it delays emergence and could thereby minimize seedling loss from frost heaving in early spring--there is an associated decrease in percentage success of emergence. Successful emergence means, in this case, one or more seedlings emerged, regardless of the number of seeds planted in the seed spot. With an increase in number of seeds per spot, for depths between 3/4 and 2-3/4 inches, percentage success of spots is increased, and, of course, the average number of seedlings per spot from a particular depth is likewise increased. With only one season's results at hand, it seems that about 4 to 8 seeds planted at 1-1/4 inches would give satisfactory results, with as much delay in emergence date as can be attained without great sacrifice of success of seed spots. Another planting of this study was made in the fall of 1955.

Mortality of seedlings.--Of the bitterbrush seedlings that emerged in the aforementioned study, 34 percent died during their first growing season. Nearly half of the mortality was attributed to damping-off, which occurred in early spring. The spring season of 1955 was unusually cool and moist, and seedling loss from damping-off seemed more common than in other years. The causative organism is not known. Another one-third of the mortality appeared to be the effect of drought, and occurred in late summer. Insects (moth larvae) accounted for less than 10 percent of the mortality, and loss from this cause was mostly in early spring. Grasshoppers were relatively few on the Payette and Boise deer winter ranges in 1955 and, although these insects are known to be able to wipe out stands of first-season bitterbrush, none of the 1955 seedlings under observation appeared to have been disturbed by grasshoppers.

There was some mortality for which no cause was apparent. Frost heaving, which in past years has been an important factor in bitterbrush seedling mortality, was not a factor in 1955.

Effect of game.--On ranges already overstocked with game animals, there is little likelihood that much artificially seeded bitterbrush can become established. Data gathered in 1955 showed many small plants to have been broken or trampled out by deer in winter or early spring, and almost all plants observed in this study had been severely browsed. In one series of plants, the average height of those remaining alive at the beginning of their third growing season was actually less than it was at the close of their seedling year. In the fall of 1955, a 1-acre game exclosure was constructed by the Idaho Fish and Game Department for the dual purpose of research and demonstration. A 5-acre area, which includes this plot, was seeded to bitterbrush by what past study and experience indicated was the best method. Plans for the next several years include close observation of the effect of game on this plantation.

Bitterbrush nursery stock.--Two small-scale studies to determine a sound method of field planting of nursery-grown bitterbrush stock were begun last year. Results to date indicate the need for control of competing vegetation close to the seedling, and show 1-0 stock to be superior to 1-1 stock in ability to survive after being planted in the field.

Rodent control.--Rodents, mainly mice, have been a problem in bitterbrush field seedlings because of their seed-gathering habits. In places they have disturbed nearly 100 percent of the seed spots within a few days of planting. With the cooperation of the Denver Wildlife Research Laboratory of the U. S. Fish and Wildlife Service, a comparison of seed treatments with three chemical substances that may either poison rodents or repel them from the seed after it is planted was carried on in the fall of 1955. Observations a few days after seeding showed one substance to have little, if any, more value than no treatment at all. The other two showed considerable promise, but observations early in the spring of 1956 will be necessary to evaluate the efficacy of the treatments.

Big-Game Range Revegetation in Utah

In the spring of 1955 a game-forage project was organized in Utah to discover plants and suitable procedures for revegetating depleted deer ranges. This is a cooperative undertaking of the Utah State Fish and Game Department, U. S. Fish and Wildlife Service, and Intermountain Forest and Range Experiment Station. Headquarters for the work is at the Great Basin Research Center.

Trials with Nursery Stock

Transplants were put out on three sites in central Utah where the soil has been derived largely from limestone or shale. Annual precipitation averages 14 to 15 inches.

Site 1 is an abandoned dry-farm in the upper sagebrush zone having a good soil with above-average moisture-holding qualities. The vegetal covering before planting was one of annuals--cheatgrass, winter rye, and Russian-thistle. Deer concentration is heavy in late winter and early spring.

Site 2, within the lower mountain-brush zone has a deep, rich soil. It is within an area where there is considerable deer concentration. The competing cover of perennial grasses was eliminated by fall plowing. Slopes on sites 1 and 2 are less than 10 percent, so machinery could be used in planting.

Site 3 is a harsh south exposure within a natural opening of Utah juniper. It has a thin soil with many interspersed boulders, preventing use of machinery in planting. Junipers on the edge of the opening were killed by singeing with a flame thrower to eliminate the drain of the moisture by juniper roots. Virtually no competing herbaceous cover exists. Deer use is heavy on such south exposures from fall until spring.

On sites 1 and 2, 8-inch furrows, approximately 3 feet apart, were made with a moldboard plow and jeep. Plants were placed in furrows, after which soil was pushed back on the roots. The jeep was then driven over the covered furrow so soil was packed around the roots. Site 3 was much too rocky and steep to make furrows, so plants were placed in holes 8 inches deep, made with a Pulaski. Thirty species of browse were used on site 1 and 36 species on sites 2 and 3.

In general all species showed best survival on the good soil of mountain-brush site 2 (table 12). Survival was nearly as good on the rocky soil of pinyon-juniper site 3, but growth was markedly less there. Both survival and growth were least on the good soil of sagebrush site 1. A big factor here was competition from annual weeds: western sand cherry, for example, had only 25 percent survival when not weeded, 50 percent survival when weeded once with a duckfoot cultivator, and 100 percent survival when weeded twice.

Table 12.--First-year survival of some of the most promising brush species on three sites: (1) abandoned dry farm in sagebrush zone, (2) mountain-brush zone, and (3) juniper-pinyon type.

	Site 1	Site 2	Site 3
Buckthorn, Dahurian (2 yr.)	2	50	93
Rhamnus davurica (3 yr.)	12	100	100
Cherry, Chinese bush			
Prunus japonica	3	90	100
Cherry, western sand			
Prunus besseyi	58	100	100
Honeysuckle, tatarian			
Lonicera tatarica	57	100	100
Lilac, common (Nebraska)	43	100	93
Syringa vulgaris (Utah)	3	95	93
Mulberry, Russian			
Morus alba tatarica	22	100	93
Olive, Russian (Nebraska)	47	100	90
Eleagnus angustifolia (Utah)	58	100	93
Rabbitbrush, rubber[1/]			
Chrysothamnus nauseosus	48	95	93
Sagebrush, big[2/]			
Artemisia tridentata	95	100	93

1/ Stem cuttings
2/ Wildings

Survival of Russian olive from Utah and Nebraska was quite similar. However, the Nebraska stock produced considerably more growth than the Utah stock and was the more vigorous at the close of this first growing season. This indicates a difference in nursery stock which is of considerable importance. Another point of interest was the better survival of 3-year than of 2-year nursery stock of Dahurian buckthorn. The larger nursery stock is also easier to handle.

Seedling transplants

Fourteen 1-inch seedlings, about 6 weeks old, were planted in a Latin-square arrangement on the mountain-brush site in 4-inch furrows, with plants 2 feet apart each way. First-season survival percentages were as follows:

Big sagebrush, *Artemisia tridentata*	100	Salt tree, *Halimodendron halodendron*	86
Fourwing saltbush, *Atriplex canescens*	93	Cliffrose-bitterbrush natural hybrid	71
Bitterbrush, *Purshia tridentata*		Cliffrose, *Cowania stansburiana*	36
local strain	86		
Boise strain	29	Mountain-mahogany, *Cerococarpus montanus*	0

The strain difference in bitterbrush is noteworthy.

Salt tree is a leguminous shrub introduced from Russia in 1924 which has grown well in the northern Great Plains. Its value as a browse plant is unknown: rodents showed a high preference for its foliage.

Seedlings of the cliffrose-bitterbrush hybrid, seed of which was collected by W. L. Robinette of the U. S. Fish and Wildlife Service in the Oak Creek Mountains in 1954, have the vigor of the best bitterbrush seedlings and are superior in this respect to cliffrose seedlings. Leaves with three lobes at the apex, as in bitterbrush, or four to seven lobes, as in cliffrose, may be found on the same bush. As in cliffrose, the leaves tend to be persistent through winter. The achenes have a vestigial plume, but otherwise they resemble achenes of bitterbrush more than cliffrose.

Seedling transplants of four species were also set out on a harsh south exposure, with the following first-season survival:

Fourwing saltbush	76
Big sagebrush	44
Bitterbrush (Boise strain)	0
Blue flax, *Linum lewisii*	62

Blue flax is a forb with remarkable ability to grow on south exposures as an associate of shrubs. It produces early green herbage which deer have been observed to relish. Palatability becomes low

in late spring when flower stalks are produced and the foliage becomes fibrous, but it does have value as a deer forage in early spring on harsh south exposures where deer concentrate.

RODENT-RANGE RELATIONS

Studies of the effects of pocket gophers on seeded range are being conducted on Monte Cristo, Cache National Forest. This open herbaceous range, in an aspen parkland at about 8,500 feet elevation, has been severely depleted by overgrazing for many years. Until it was artificially seeded, this open type was dominated by tarweed (*Madia glomerata*), and loss of topsoil has been widespread. Table 13 shows grass production on two 3-acre seeded areas--one with close gopher control, the other with a heavy population of pocket gophers.

Table 13.--Grass production by soil type with gophers controlled and present, 1953-1955

	1953	1954	1955
	Pounds per acre, green weight		
Gophers controlled			
Gray soil	2,232	817	1,870
Brown soil	1,780	470	1,570
Gophers present			
Gray soil	1,445	420	1,000
Brown soil	585	120	150

The two areas are believed to be about equal in potential productivity and both have gray and brown phases of the same soil type. The brown soil is much more heavily infested with gophers than the gray. Gophers are primarily responsible for the differences in production shown. They affect grass plants in the following ways:

1. Their winter casts melt out in spring and partially seal the soil against water infiltration. This, together with numerous tunnels, contributes to drought and is especially detrimental to seedlings.

2. Plants are undermined and sometimes pulled into the gopher runways.

3. Plants are killed by gopher digging and by being covered with dirt mounds.

4. Plants are clipped just beneath the root crowns--presumably underneath a snow cover.

Soil moisture samples and permeameter readings indicate greater water penetration on the gopher-free than on the gopher-infested area.

SPROUTING OF BITTERBRUSH FOLLOWING TOP REMOVAL

Much bitterbrush, one of the most important browse species on western ranges, has been burned in recent years, chiefly as a result of widespread use of fire for sagebrush eradication. Although but little sprouting of bitterbrush has been observed in the western Great Basin and California, sprouting from the root crown following burning is common in eastern Idaho. Because of the importance of sprouting in the maintenance of satisfactory stands of bitterbrush, a study was made on the Upper Snake River Plains of the relative effects of fire and complete top removal on this shrub.

Sprouts on both burned and severed bitterbrush plants originated in two different ways: from an existing mass of dormant buds wholly or partly encircling the stem at ground level or from a callus of meristematic tissue formed beneath the bark after treatment and encircling the stem. An examination of a large burn indicated that dormant bud masses were present on 70 percent of the bitterbrush, but many of these had been killed by fire. Nearly twice as many plants sprouted from the callus formed beneath the bark as from existing buds.

Fifty percent of the experimentally burned plants produced sprouts, whereas nearly 72 percent of the bushes sprouted following top removal by clipping. Date of treatment had little effect on number of plants that sprouted following clipping, but burning in May and June resulted in more sprouting than in other months. Burn intensity strongly affects sprouting; date of burning--and corresponding soil moisture--appears important only as it causes differences in intensity. There was a fairly high mortality of plants that sprouted following both burning and top removal, and losses were greater among sprouts from burned than from severed plants.

At every date, more bushes sprouted following experimental burning or clipping on a former burn than on a previously unburned area. This indicates a selective action of fire and suggests that sprouting of bitterbrush is influenced by genetic as well as environmental factors.

Grazing Pressures and Plant Composition

Excessive grazing pressures by different kinds of animals have produced striking ecological changes. Table 14 illustrates such changes in the mountain-mahogany type grazed mostly in winter by deer and in spring and fall by livestock.

Table 14.--Plant growth and range condition in relation to grazing use on curlleaf mountain-mahogany type

Forage	Good condition range	Range heavily overgrazed by: Deer only	Cattle only	Sheep only	Cattle & deer
	Plant growth-lbs. per acre air-dry				
Curlleaf mountain-mahogany	815	15	1,315	750	55
Sagebrush	125	135	240	465	290
Other shrubs (low quality)	--	--	50	20	200
Perennial forbs	230	190	18	7	20
Perennial grasses	925	1,010	7	7	35
Annuals	Trace	Trace	40	65	100
	2,095	1,350	1,670	1,314	700
Percent bare soil	9	13	26	23	34

For these curlleaf mountain-mahogany ranges it is evident that:

1. Range in good condition has a mixture of browse, forbs, and grasses well suited to grazing by both deer and livestock and supplying adequate soil protection.

2. Overgrazing by deer alone destroys choice browse species. (In extreme cases sagebrush also is destroyed.) Ground cover remains good on the better soils because grasses fill in where shrubs die (but on dry, steep slopes of loose soil, material soil disturbance may result).

3. Heavy overuse by cattle or sheep alone destroys the perennial grasses and forbs and permits shrubs such as sagebrush and curlleaf mountain-mahogany to increase. Soil is exposed to erosion.

4. Overgrazing by both deer and livestock destroys palatable grasses, forbs, and browse, and permits the increase of low-value shrubs and annuals. Soil is exposed to erosion.

Big Game-Livestock Competition

Deer-cattle studies on Oak Creek range in Utah revealed that one-fifth of the summer range and one-third of the winter range were grazed heavily by both deer and cattle. Management of this deer-cattle range should be based on proper utilization of forage on these key areas where competition for forage is most severe. In summer deer fed mainly on forbs and browse, while cattle relied mainly on grass if available. Most choice deer foods were used somewhat by cattle but deer used little grass except for a short period in early spring. Browse was the main deer food in winter and most of their choice browse species were used by cattle spring and fall. On all deer-cattle ranges studied maximum sustained grazing use is limited by (a) proper use of perennial grasses for exclusive cattle grazing, (b) proper use of palatable shrubs and forbs for exclusive deer grazing, and (c) proper use of shrubs and forbs palatable to both kinds of animals for maximum combined deer-cattle grazing.

Sheep compete more with deer for forage than do cattle, both in areas grazed and in choice of forage. On Monroe Mountain in Utah sheep and deer both grazed about 80 percent of the area intensively. The greatest utilization by deer occurred on the areas used in common. Forbs and browse were prominent in the summer diet of both deer and sheep. Most of the choice deer forage species were also good sheep forage. On summer range 6 of the 10 species most prominent in each diet were also prominent in the diets of both. The chief difference was in a much greater utilization of grass by sheep. Spring diets of sheep and deer on a depleted foothill range were very similar and consisted chiefly of young grasses and browse. Browse species grazed by sheep in late fall were the same as those preferred by deer in winter.

CATTLE GAINS AT BENMORE

The cooperative study at Benmore with the Animal Husbandry Department of the Utah State Agricultural College, involving 12 spring grazing treatments on twenty-four 100-acre pastures of crested wheatgrass, was continued through the eighth consecutive year in 1955.

Whereas at the outset heavily grazed pastures produced the highest cattle gains per acre, 1955 was the second consecutive year in which gain per acre for animals over 6 months of age was less on heavily grazed than on lightly grazed pastures. (Per-acre gains on moderately grazed pastures have exceeded those on heavily grazed pastures for several years.) In 1955, average gains per acre on lightly, moderately, and heavily grazed pastures were 27.8, 29.1, and 22.5 pounds, respectively. When the calf gains are added, total gains per acre become 36.0, 38.0, and 33.9 pounds for the respective treatments.

Average daily gains continued high in 1955 (table 15). It is readily seen that cows with calves are affected more by heavy grazing than either dry cows or yearlings. As with older animals, calf gains are lower under heavy grazing than for the light and moderate intensities of use.

Table 15.--Average daily gains per head of different classes of cattle under light, moderate, and heavy grazing from 1952 to 1955, inclusive

Class of cattle	Light	Moderate	Heavy
Calves	1.86	1.84	1.72
Yearlings	2.68	2.51	2.30
Cows with calves	3.09	2.82	1.89
Dry cows	3.46	3.39	2.76

CONTROL OF UNDESIRABLE PLANTS

Sagebrush Control by Burning vs. Rotobeating, Railing, and Spraying

A study was started on the Upper Snake River Experimental Range in 1952 to compare the effects of sagebrush burning with three other accepted methods of sagebrush control that also maintain the native herbaceous understory. Five adjacent areas, approximately 12 acres each, were selected in a dense stand of big sagebrush with a good understory of perennial grasses and forbs, and were treated as follows: burned, rotobeaten, railed, and sprayed with 2,4-D. One was left as an untreated check.

Data on herbage production available to livestock in air-dry pounds per acre were collected prior to treatment, 1 year after, and 3 years after treatment.

All methods resulted in substantial reduction in big sagebrush, both in production and numbers of plants (tables 16 and 17). Unfortunately, results from the sprayed area do not typify the intensity of sagebrush kill that can often be obtained by using 2,4-D. The poor kill with it in this instance was attributed to poor distribution of spray rather than inherent limitations of the method. Railing was the least satisfactory method in killing sagebrush. Living sagebrush plants on the burned area are all from seed germinating after the burn and are relatively small, whereas some of the plants on the other areas are older plants surviving the treatment.

Table 16.--Numbers of sagebrush plants per 48-square-foot plot before and after treatment

	1952 Prior to treatment	1953 First year after treatment	1955 Third year after treatment
Untreated	11.6	10.4	11.9
Burned	9.8	1.5	2.8
Rotobeaten	10.7	2.0	3.6
Railed	10.7	3.8	6.2
Sprayed	11.1	3.5	4.3

Table 17.--Available air-dry production expressed in pounds per acre, and as percentage of production on untreated check area

	1952 Prior to treatment		1953 1st year after treatment		1955 3d year after treatment	
	Pounds	Percent	Pounds	Percent	Pounds	Percent
UNTREATED						
Grass	133		126		202	
Forbs	35		53		71	
Sagebrush	200		247		296	
BURNED						
Grass	134	101	160	127	292	144
Forbs	49	140	267	504	268	377
Sagebrush	183	92	1/ T	0	42	14
ROTOBEATEN						
Grass	149	112	199	158	483	239
Forbs	26	74	109	206	137	193
Sagebrush	202	101	28	11	45	15
RAILED						
Grass	125	94	154	122	282	140
Forbs	57	163	170	321	177	249
Sagebrush	157	78	57	23	106	36
SPRAYED						
Grass	163	122	213	169	361	179
Forbs	46	131	54	102	78	110
Sagebrush	165	82	99	40	115	39

1/ T = seedlings

Grass, which increased on the untreated area over the 3-year period, increased much more on the areas where sagebrush had been controlled (table 17). Although the increase in available grass on the railed area was about the same as that on the burned area, and the increase on the sprayed area was somewhat greater, considerable grass also occurred on the railed and sprayed areas that was not considered available because of standing shrubs. Rotobeating, on the other hand, resulted in the most available grass primarily because there was no initial reduction in vigor as in burning, and the impeding shrubs were knocked down to make all the grass accessible. Apparently production of grass is continuing to increase under all treatments as vigor is improved and newly established individuals come into production.

Burning favored available perennial forb production markedly more than any other control method, and spraying less. An increase in available forbs also occurred with rotobeating and railing. In contrast to the reaction of grasses, forbs responded most markedly the first year after treatment, and since then their production has tended to level off.

It is interesting to note nature's compensating play when a catastrophe occurs to a particular component of vegetation. Upon an immediate reduction of shrubs, herbaceous species vie for the released moisture, nutrients, and light. Apparently certain forbs are best able to take initial advantage of this available resource by rapidly increased growth. This is illustrated by the great increase in forb production the first year after treatment. Grasses appear to be a bit slower in exerting competitive pressures, but are able to increase longer at the expense of the forbs, as illustrated by the continued increase of grass production and leveling off of forb production. These generalizations need to be qualified, of course, by the recognition that some species of forbs or grass respond differently than others to burning, spraying, railing, and rotobeating.

Burning is by far the least expensive of the four methods used to control sagebrush. Costs of the different methods may vary considerably, but the following figures are indicative of comparative costs per acre: burning, $0.70; rotobeating, $3.00 to $5.00; railing (twice over), $2.00 to $2.50; spraying with 2 pounds 2,4-D, $2.50 to $3.00.

Changes Following Goatweed Control

Composition transects established at Milan in northeastern Washington to follow vegetal changes brought about by control of goatweed (*Hypericum perforatum*) with the beetle *Chrysolina gemellata*, indicate not only degree of control but also the plant species

filling the void created by reduction of goatweed. Although beetles were planted in 1951, their effect was not apparent until after the transects were established in 1953.

Between 1953 and 1955 goatweed in the vicinity of the planting was reduced from an initial 23.5 percent composition to 0.9 percent (table 18). On this site cheatgrass (*Bromus tectorum*) and Italian bentgrass (*Agrostis interrupta*), both annuals, replaced goatweed in the stand. During the same 2-year period amount of litter on the ground decreased and exposure of bare soil increased.

Table 18.--Composition changes on goatweed-dominated range determined 3/4-inch loop method (650 loops distributed on 8 transects)

Item	Percent composition 1953	Percent composition 1955
Bare soil	14.8	22.5
Erosion pavement	1.0	0.8
Rock	4.3	2.8
Litter	43.4	30.5
Moss	--	2.5
Agrostis interrupta	5.4	13.8
Apocynum pumilum	0.1	0.2
Bromus tectorum	2.9	18.5
Hypericum perforatum	23.5	0.9
Lappula sp.	2.6	--
Lepidium sp.	--	4.8
Lotus purshianus	0.5	1.8
Poa secunda	0.2	0.1
Others	1.3	0.8

Range Weeds in Montana

Initial phases of the range research problem analysis in Montana have revealed the spread of noxious weeds on both range and forest lands as a major problem. As would be expected, invasion by these weeds has been most rapid on areas where the native vegetation has been severely disturbed, as on overgrazed ranges and cut-over timber lands. However, there are indications that some of the noxious species are also invading grasslands in fairly good condition.

Some of the most abundant weeds are goatweed (*Hypericum perforatum*), Canada thistle (*Cirsium arvense*), Russian knapweed (*Centaurea picris*), wyethia (*Wyethia amplexicaulis* and *W. helianthoides*), and leafy spurge (*Euphorbia esula*).

Sagebrush (Artemisia tridentata) and cheatgrass (Bromus tectorum) might also be considered in the category of troublesome weeds, although, in contrast with the foregoing species, considerable information is available on their ecology and methods of control. Goatweed is very abundant on the west side of the Continental Divide in Montana, but is of little consequence on the east side. Canada thistle is widespread in the lowlands; its occurence on national forests is confined to relatively small patches. Russian knapweed is very abundant in some areas, particularly in the Bitterroot Valley and on adjacent areas of the Bitterroot and Lolo National Forests. Wyethia is abundant on limited portions of the Gallatin and Beaverhead Forests, but elsewhere is of minor importance. Leafy spurge is confined mostly to cultivated lands but has invaded some range and forest lands, particularly on cutover areas.

Control of noxious weeds on wild lands is important because these plants are replacing desirable forage species and in some cases may be preventing proper reproduction of forest trees. Weed infestations on range and forest areas are also a source of contamination for cultivated lands, which is a cause of considerable concern to weed control districts. This situation in Montana and elsewhere has led to the introduction of, a number of bills in Congress pertaining to noxious weed control on public lands.

Although certain direct control methods have been effective on cultivated areas, they are often too expensive for use on wild lands. If indirect control through management is to be achieved, it will be necessary to obtain information on the ecology of these weeds, particularly about the conditions under which they invade new areas. Ecological information is also needed to provide proper management for preventing reinvasion of weeds following eradication. In the case of cutover areas, it may be worthwhile to investigate the possibilities of seeding with herbaceous species to prevent invasion of noxious weeds until timber reproduction again gains control.

Halogeton on the Desert Winter Range

In the fall of 1952 halogeton (H. glomeratus) was found on a small area adjacent to the playa on the Desert Experimental Range. The plants were small and few, scattered over approximately 8 acres along the edge of the salt flats where Kochia vestita, Atriplex confertifolia, Sarcobatus vermiculatus, and Salsola kali tenuifolia occur sparsely. Halogeton plants were established on bare, saline soil but seemed to prefer soil mounds around established plants. No other halogeton infestations were found adjacent to the Desert Experimental Range in 1952, but in 1953 a heavy infestation was located approximately 4 miles southeast along the drainage into the experimental area. Probably this was the seed source for the plants found the previous year.

By 1953 the small infestation within the experimental area had spread 2 to 3 miles across the playa and seedlings were found in the vegetation along its borders. Infested spots were also found in Antelope Valley 10 miles to the west, in Snake Valley 1 mile to the north, and in Pine Valley along the eastern boundary and southeastward from the Experimental Range.

In June of 1954, four small areas in white sage and shadscale types were seeded to halogeton. On each area two plots approximately 8x8 feet were planted. One plot was cleared of vegetation. On the other the seed was raked in among the native plants. All plots produced halogeton plants in 1954. Because of drought the plants were small, averaging only 5 to 6 inches in height, and the number per plot varied from 8 to 23. The plants apparently produced seed on most of the plots and in 1955, another drought summer, plants were found on three of the areas.

On area No. 1 in a good white sage stand, halogeton had spread approximately 130 feet, and the plants varied from 1 to 5 inches in height. On area No. 2 in mixed shadscale-white sage, no halogeton plants were found: either the plants did not mature seed, the seed did not germinate, or seedlings failed to become established. On area No. 3 on heavily grazed range, halogeton spread approximately 40 feet and plants averaged 3 to 8 inches. On area No. 4 on moderately grazed range in the shadscale-winterfat type, halogeton spread only about 8 feet and the plants were 8 to 10 inches tall with 15 to 20 plants in the original cleared plot. These preliminary observations suggest that halogeton cannot be excluded from desert-shrub range, but perhaps it can be suppressed by the perennial vegetation, and its effects on livestock minimized, if the range is in good condition.

Halogeton is now well distributed around the Experimental Range. It occurs on the road at several places along the eastern boundary; it also occurs along the western boundary in Antelope Valley. By the end of 1956 it will probably surround the Experimental Range on all sides.

ASPEN SITE POTENTIAL

The aspen·type includes many openings which often have a herbaceous or herb-shrub cover very different from the understory of the aspen itself. As a rule, vegetation of openings is sparser and shorter, and tends to include a smaller proportion of desirable forage species, than vegetation beneath the aspen canopy. In trying to visualize productive potentialities of the type, the question arises as to whether this difference is natural, or whether, like so many changes in range vegetation, it has been brought about by heavier grazing in the openings. Observations have shown that there

is a tendency, marked with cattle and somewhat less marked with sheep, for utilization of forage to be heavier in openings than under extensive stands of aspen. (At the edges of some stands, and in small patches of aspen where animals shade up, the reverse is often true.)

A practical application from knowledge of potential productivity is found in judging range condition. If the potential in openings is less than that under the aspen canopy, then the openings and understory vegetation cannot be judged by the same criteria. If the productive potential in the two habitats is the same, not only can their condition be judged by the same criteria, but perhaps differences between them may be significant as indicators of range condition. Finally, if the productive potential of open-growing vegetation is greater than that of understory vegetation, criteria needed for the openings should be the more exacting.

A clue to the answer is provided by the fact that, in those few stands which have escaped heavy grazing for many years and which are therefore presumed to be nearer to pristine than most range, differences in production under the canopy and in the open are much less than the differences on the prevailingly heavily grazed range. In fact, there is a suggestion that production in the openings may actually be greater than production under the trees, an opposite difference to that encountered on heavily grazed range. The trouble with this evidence is that such ungrazed areas are few and small and are mostly in rough, rocky terrain that is not entirely typical of the broad aspen type which is usually found on gentle slopes and flats with rather deep soil.

In order to measure potential productivity, plots were seeded at four locations in Ephraim Canyon in central Utah in 1950. One set of plots at each location was put in the open near an aspen stand, and two sets of plots were established within the stand, one of which was trenched each year of the study to a depth of 2 feet to cut the aspen roots. The trenches were refilled. Subplots were seeded to Bromus carinatus, Elymus glaucus, Heracleum lanatum, and Rudbeckia occidentalis. Considerable difficulty was experienced in getting full stands of some species, and since Bromus was most uniformly successful, it will be used as an example to summarize the salient results.

Table 19 shows that production on the open plots exceeded that of the untrenched plots under the aspen. This relation is consistent for Bromus, and, if poor stands are excluded, for Elymus and Rudbeckia. No fully stocked open stands were obtained with Heracleum. These results indicate that the productive potential of the openings is fully as great as that under the aspen, and probably is greater.

Table 19.--Air-dry production of *Bromus carinatus*, in grams per 9.6 sq. ft., 1953

Elevation of site	Open	Under aspen: Untrenched	Under aspen: Trenched
Feet			
9,000	128	30	171
8,800	116	58	133
8,450	47	17	97
8,050	51	36	89

Turning now to the figures for trenched and untrenched plots under the aspen, it is seen that production on the trenched plots is consistently higher than on the untrenched plots. This is true for the other three species also. It is clear, then, that aspen does suppress understory vegetation.

It is concluded that the productive potential may be greater in openings than under the aspen canopy despite the advantages provided by the overstory in shade, lower evaporation, soil fertilization through leaf fall, etc. This study confirms the evidence from natural areas showing that potential production of herbaceous vegetation in aspen openings is at least as great as, and probably greater than, potential production within the aspen stand. Probably the benefits conferred on the understory by the aspen are outweighed by the demands of aspen for soil water.

This study provides a basis for defining condition in the aspen type more accurately than has heretofore been possible. For extensive areas of aspen range to be in satisfactory condition, the production of herbage in openings should be at least as great as production under the aspen canopy, and perhaps one may say that for excellent condition productivity should be materially greater. Probably--from observation of natural areas--species composition should not be greatly different in openings and under the aspen overstory.

RANGE RESEARCH METHODS

Interpretation of Vegetal Changes from Loop Hits

One of the primary objectives in the development of the 3-step method was the simple and accurate measurement of vegetal changes. The data obtained from the precise part of the method, the loop readings, are intended to serve as benchmarks for future readings. Presumably the changes recorded in the loop readings for a specific

item over a period of time, coupled with other extensive wide-scale estimates, are indicative of trends. The reliance which the observer can place on his conclusions regarding trends depends largely on the magnitude of differences recorded by the loop and on his knowledge of the vegetal type under consideration.

A study was made at the Upper Snake River Experimental Range to test the correlation between changes in loop hits and changes in root crown areas. The most abundant species on the site chosen for the study were Agropyron spicatum and Balsamorhiza sagittata and the site was classified in good condition.

Table 20 shows total number of plants, total area occupied by root crowns, and average size of root crown area for each species. It is of interest to note that the root crowns of Balsamorhiza occupied more area than those of Agropyron, although the Agropyron plants were about 10 times more numerous. Comandra is also of interest because it was represented by almost as many plants as Balsamorhiza and yet its total root crown area was insignificant by comparison.

Table 20.--Amounts of the three measured species on 8 belt transects on the study area

	Agropyron spicatum	Balsamorhiza sagittata	Comandra umbellata
Total plants	2,250	268	249
Total root crown area (cm.^{2})	4,679	6,289	24
Av. root crown area (cm.^{2})	2.08	23.4	0.09

In this study, the total root crown area of Agropyron spicatum, Balsamorhiza sagittata, and Comandra umbellata was determined by measuring the cross-sectional area of every plant on each of 8 belt transects 9 inches wide and 100 feet long, and loop readings were taken at 6-inch intervals, i.e., 200 readings per transect. Random removals of measured root crown areas followed by loop readings were then made three times on each transect. This procedure resulted in two independent indices of change of 100 loops each (100 loop readings at half-foot marks and 100 at foot marks) and one index of change of 200 loops or a total of three indices for each change on every transect. Since there were three removals (changes) made on each transect the total number of indices obtained for a transect was 9; six 100-loop and three 200-loop indices.

When the root crown areas and their associated loop-hit values were plotted and the regression of root crown area on loop hits computed it was evident that loop hits did not give a satisfactory index to the amount of surface occupied by root crowns. For

example, 8 loop hits indicated 173 sq. cm. of Agropyron on one plot, 342 sq. cm. on another, and 638 sq. cm. on still another. These differences were observed on transects where the sampling consisted of 200 loop readings per transect. Where 100 loop readings were taken, the differences were greater in most cases.

The inability of the loop technique to furnish a satisfactory estimate of root crown area is incidental to the primary objective of this investigation which was to test the ability of the loop to detect change in root crown area.

When the average root crown areas of the 8 transects, as determined by actual measurement, are compared with the average loop readings, the changes in root crown areas are rather accurately reflected by the changes in loop hits. Table 21 illustrates this relation based on averages of 8 transects for Agropyron. Out of the 9 indices of change provided by the loop hits as shown above, one differs from the actual by 11 percent (88% - 77% = 11%); the other 8 are within 9 percent or less of the actual change. The data for Balsamorhiza showed a correlation between changes in loop hits and changes in root crown areas that was equally good. There was little gained with either species by increasing the number of loop readings from 100 to 200 per transect.

Table 21.--Loop hits on 8 transects at 100 or 200 loops per transect as known amounts of Agropyron were removed

Removal	Av. root crown area		100 loops 1/		100 loops 2/		200 loops	
	Cm^2	Percent	Loop hits	Percent	Loop hits	Percent	Loop hits	Percent
0	585	100	5.4	100	6.5	100	11.9	100
1	514	88	4.4	81	5.0	77	9.4	79
2	374	64	3.6	67	4.5	69	8.1	68
3	263	45	2.4	44	3.5	54	5.9	50

1/ Loop hits at foot marks
2/ Loop hits at half-foot marks

It is obvious from this tabulation that 8 transects of 100 loops each provided a good index to the changes that actually occurred on the site studied. However, in the practical application of the loop technique the observer is likely to have fewer than 8 transects on which to base his estimates. In order to determine the minimum number of transects required to furnish a good index to change, under the conditions of this study, the following procedure was adopted. Three groups of 7 transects each were chosen at random

from the total of 8 transects. The average root crown areas and loop hits of each group were determined and compared. This same technique was used with groups of 6, 4, 3, and 2 transects each. The results of these group comparisons are shown in table 22.

Table 22.--Percent of 100-loop and 200-loop indices of change in root crown area of Agropyron and Balsamorhiza that differed from the actual change by 10 percent or less; data obtained from averages of groups of 2, 3, 4, 6, and 7 transects each

Number of transects per group	Agropyron		Balsamorhiza	
	100 loops	200 loops	100 loops	200 loops
	Percent		Percent	
7	78	89	95	100
6	67	100	50	100
4	56	78	50	67
3	44	56	61	67
2	39	44	28	33

It is of interest to note that when the number of transects dropped to 6, only two-thirds of the indices obtained from the 100 loop readings for Agropyron and only half for Balsamorhiza were within 10 percent of the actual changes. Table 22 also shows that in every instance the percentage of indices falling within the allowable 10-percent error was greater when the number of loops read per transect was increased from 100 to 200. With 7 transects there is some doubt as to whether the increase in accuracy afforded by the 200 loop readings is sufficient to justify the concomitant increase in time and effort. Where 6 transects were used there is no such doubt.

The 10-percent standard of accuracy chosen for this study is, of course, arbitrary. If the observer is willing to accept larger differences he can obviously get a larger percentage of his indices within his acceptable error without increasing the number of transects in the sample. On the other hand, if only smaller differences are considered significant, the volume of sampling must be increased in order to maintain a selected percentage of loop indices within the acceptable limits. If the 10-percent error is acceptable, it is apparent from table 22 that in order to obtain a satisfactory loop index of change in these two dominant species a minimum of 7 transects of 100 loops each is required. If the loop readings are increased to 200 per transect, 6 transects will suffice.

Although Comandra umbellata, the third species tested, occurred on every transect, only one loop hit was recorded on it during the entire test. It is therefore clear that, to detect changes in minor species in the stand, much more intensive sampling is needed than even 8 transects of 200 loops each.

Errors in reading the loops occurred 8 times, i.e., a hit recorded at one reading was missed in a subsequent reading or vice versa, even though no change had been made and the steel tape was left in place between readings.

WATERSHED MANAGEMENT RESEARCH

This division is concerned with finding solutions to three kinds of watershed management problems on the forest and range lands of the Station territory. Part of the study program is aimed at determining how to restore control of runoff and mantle stability on lands where plant cover has been depleted and erosion of slopes and channels has been accelerated by improper land use. Other studies are being made to determine how to maintain satisfactory watershed conditions while providing for use of the timber, forage, and other land resources. A third group of studies is directed toward finding ways of managing the vegetation and soil so as to increase the amount or improve the timeliness and quality of water yields.

Progress was made on all three of these major problems during the past year through continuation of experimental studies at the Great Basin Research Center in central Utah, the Wasatch Research Center in northern Utah, and the Boise Research Center in southwestern Idaho. In addition, an analysis of the watershed problems in the Montana, northern Idaho, and eastern Washington portions of the Station territory was undertaken at the Missoula Research Center. This analysis, though not yet complete, shows there are many watershed problems in both the upper Columbia and upper Missouri River basins on which research is needed. These needs are to be given further consideration in the coming year as a basis for developing a watershed management research program and assignment of study priorities.

WATERSHED RESTORATION

Floods continued to plague the region in 1955. Some came in the summer following localized, short duration but high intensity rains. Others came in mid-December following prolonged rains that melted much of the snow which had begun to accumulate on the mountain slopes. Virtually all of the summer rain floods and much of the runoff in the rain and snowmelt floods came from damaged watershed lands.

The summer floods followed a familiar pattern. The Cedar City area in southern Utah, and the Mt. Pleasant area in central Utah were again damaged, as they have been many times in recent years. The source of the newest floods, like those of the past, were high elevation depleted range lands that have lost their capacity to absorb and store water. However, summer floods were not confined to Utah. Similar flash floods from similarly damaged summer range lands also occurred on tributaries of the Salmon and the Boise Rivers in central Idaho.

The most publicized of the winter floods occurred in the Reno, Nevada area from the Truckee river watershed on which there has been widespread depletion of the plant cover by repeated timber cutting, fires, and overgrazing. There, in a 5-day period in December, from 10 to 20 inches of warm rain melted much of the snow that had accumulated. A discharge of 18,000 c.f.s.--6,000 c.f.s. above channel capacity--caused damage in the Reno area of about $5,000,000. Much greater damages were averted only because an inflow of cold air changed the precipitation during the following 3 days from rain to snow.

Similar, prolonged rain on snow also produced major floods on the Little Salmon, Payette, and Boise Rivers in Idaho. Discharges on the Payette River rose from 5,000 c.f.s. to 26,000 c.f.s. in 18 hours, a new record for that stream. The full extent of damages in the Idaho areas has not yet been determined. However, it is known that great quantities of sediment were carried into downstream reservoirs from ripped channels, washed out highways, poorly covered burned-over lands, and deeply gullied logging haul roads and skid-trails.

Watershed Restoration, Davis County Experimental Watersheds

The behavior of streamflow in the Parrish and Centerville basins of the Davis County Experimental Watershed during the period 1936 to date is providing much needed information about the effects of upstream watershed restoration measures on perennial water yields derived largely from snowmelt. These areas are also providing information on the control of torrential summer rains.

The Centerville and Parrish watersheds are each about 3 square miles in size. They are adjacent to each other and drain a portion of the western slope of the Wasatch Mountains. Elevations in both extend from about 4,500 to 9,000 feet. The land use and flood history of the two areas is quite different. In the Centerville watershed, the mixed tree, brush, and herbaceous vegetation has never been seriously depleted, though it has been moderately grazed for many years. This area has produced no summer storm mud-rock floods since settlement began in the valley below over 100 years ago. In Parrish watershed, serious plant cover depletion occurred on headwater areas because of overgrazing. Four devastating mud-rock floods occurred from this watershed in 1930. The area was then closed to grazing and the flood-source areas were contour trenched and seeded to perennial grasses in 1934.

It has been determined that mud-rock floods can be generated on depleted lands in the Davis County Experimental Watershed by as little as 0.50 inch of rain, if rainfall rates exceed 1.50 inches per hour for 5 minutes. There have been 20 such storms on the Parrish watershed since 1936. During 8 of these storms, maximum rates exceeded 3.00 inches per hour, and on 2 occasions they exceeded 5.00 inches per hour. Similar rains have occurred in the Centerville watershed. No mud-rock floods have occurred on Parrish Creek since the upstream restoration measures were installed, nor have any occurred on Centerville Creek. By contrast, nearby impaired watersheds not so treated have continued to produce floods under the impact of rains of less intensity than some recorded in the Parrish and Centerville watersheds.

Parrish Creek is now producing high-quality water. Instead of discharging 100-ton boulders and other debris at rates of 9.00 acre feet per square mile of watershed area per year, as it did during and following the 1930 floods, streamflow from Parrish Creek now runs as clear as in Centerville Creek. Water from both streams is diverted directly into both domestic and irrigation water systems.

Restoration of the plant cover on the flood-source areas in Parrish Creek has resulted in a gradual decline in annual water yields amounting to about 1.50 inches over the past 18 years. This decrease has occurred only during the months of March, April, and May when water yields from snowmelt are locally abundant. There has been no discernible change in water yields during the summer and fall months when water is in highest demand. The restored plant cover in many places is now producing 3,000 to 4,000 pounds of good-quality forage where only 500 to 700 pounds of inferior weeds were produced before.

There has been a downward trend in the magnitude of snowmelt peak discharges on Parrish Creek. Though this stream continues to produce greater snowmelt peak discharges than Centerville, the magnitude of the difference between the discharges has been reduced about 50 percent. Maximum daily runoff from Parrish Creek is now tending to occur later in the spring. Whereas it tended to occur 3 or 4 days earlier than Centerville during the years 1936 to 1940, it now tends to be from 3 to 4 days later.

The runoff behavior of Parrish Creek probably has not been fully restored to normal. There is room for further improvement in the plant cover on some of the flood-source areas. More time will also be required for the ripped channels to become refilled. As the condition of this watershed improves, annual runoff may decrease still more. However, there should also be greater control of storm runoff, decreasingly less sediment production, a further lowering and delay of snowmelt peaks, and even greater forage production.

Restoration of Subalpine-Herbaceous Range Watersheds

The artificial reseeding that was done on the depleted Area B watershed at the Great Basin Research Center continues to be effective in providing virtually complete control of summer storm runoff and of sediment production. For the third year in succession, sediment yields were too small to measure and runoff was equally negligible. Meanwhile, plant cover density has increased about 50 percent and the area is now producing about 3 times more forage than it did when last inventoried in 1951. As shown below, there has been a substantial increase in perennial grasses, a decrease in weedy forbs, with little change in litter.

	1951	1955
Plant cover density (percent)	20	33
Live vegetation	14	28
Litter	6	5
Range forage (pounds/acre)	1,100	3,000
Grasses	280	2,600
Forbs	820	400

The new grasses are both well dispersed and in healthy condition. The density of both the grasses and litter is expected to increase in the next year or two. After optimum cover conditions are developed this area is to be used for testing effects of grazing use on its hydrologic characteristics as a means of determining maximum safe amounts of use.

Pleasant Creek Watershed Evaluation Study

During the year the Station provided technical guidance for a study of the hydrologic and productivity effects of an upstream restoration program in the Pleasant Creek watershed in central Utah. This is one of the first areas to be treated under provisions of the Small Watershed Demonstration Project item of the Agricultural Appropriations Act of F. Y. 1954.

As part of this study, infiltrometer tests and records of forage production were made this summer on a variety of flood-source areas prior to their treatment by protection from grazing, plowing and reseeding, and contour trenching. Repeat measurements on the permanently staked plots are scheduled for 1956.

Analysis of the first year's data has not yet been completed. However, the data show very obvious inverse relationships of amount of plant and litter cover to infiltration, storm runoff, and soil erosion. There are variations in these relations also due to differences in the structure and pore space characteristics of the soil.

To supplement the infiltrometer and transect study, runoff plots equipped with sediment catchment basins were established on several paired areas having well developed gullies. One of each pair was not treated, the other was contour trenched and seeded. Sediment production measurements are to begin on these areas in 1956 and will be continued through 1958.

WATERSHED MAINTENANCE

A twofold increase in timber harvesting in recent years and continuing demands for the grazing of livestock and big game have accentuated the problem of maintaining effective control of runoff and soil stability on the watershed lands of the Station territory. During the past year, progress was made on two erosion control studies on the ponderosa pine lands of Idaho, and on a range watershed study in central Utah.

Logging Disturbance-Sediment Production Study

During the years 1953 and 1954, a study of the effects of cutting and logging ponderosa pine on sediment production was undertaken in the Boise Basin Experimental Forest near Idaho City, Idaho. Twenty small watersheds were included in the study, of which 16 were cut and logged, and 4 were left in virgin condition. Debris basins for trapping sediment were installed on all watersheds. In 1955, data were obtained on the area of the forest floor that was disturbed by logging, the amount of sediment trapped in the debris basins, and the amount of sediment that has been temporarily trapped between the eroding source areas and the debris basins.

The areal extent of logging disturbance ranged from 4.0 to 13.5 percent per study compartment. Haul roads were responsible for 45 percent of the disturbed area, skidtrails for 40 percent, and log loading areas 15 percent.

The amount of eroded sediment was too small to be measured on 7 of the logged watersheds but ranged from 1 to 216 tons per square mile on the other logged areas. The greatest sediment production came from watersheds in which haul roads crossed or paralleled a portion of the main drainage bottom.

These first measurements were taken prior to December 1955, when unusually heavy rains on snow caused very serious erosion on extensive areas of ponderosa pine lands in the vicinity of the experimental forest. The advent of heavy snow precluded an examination of the effects of the rainstorm on the experimental areas. These effects will be determined in the coming year following the disappearance of the snow pack.

Postlogging Erosion Control Methods Study

During the past year the first measurements and observations were obtained on 4 erosion control areas on the Boise and Payette national forests. Part of this study is to evaluate the effect of gradient, spacing of cross ditches, and grass seeding on sediment production from temporary logging trail roads. Another part is to test the effectiveness of different types and spacings of erosion control measures on skidtrails. A large mass of data from observations taken immediately after spring snowmelt and after the occurrence of high intensity summer rains is now being analyzed.

This study was expanded during the past year by adding a more comprehensive test of reseeding measures on 2.8 miles of logging road within the Little Owl Creek timber sale area on the Boise National Forest. This phase of the study involves the testing of 9 promising grasses, 4 methods of planting, and site treatment by fertilizer and mulch. The tests are replicated on north and south exposures. The results of this study are expected to lead to more certain and effective erosion control on logging roads than has been experienced to date.

Range Watershed Maintenance Study

With help from the Boise and Wasatch Research Centers, a start was made on a study to determine the safe limits of grazing reseeded subalpine-herbaceous range in the headwaters of Manti Canyon on the Manti-LaSal National Forest in central Utah. The study area is typical of extensive areas of high elevation depleted range. It was plowed and seeded to grass in 1952. Prior to treatment, paired one-half acre plots were located on a variety of slopes, aspects, soils, and plant cover types. One plot in each pair was not treated. The entire area has been protected from livestock grazing since 1952.

As a first step in the study, infiltrometer tests and plant cover observations were made on the treated and untreated plots during the past summer. Analysis of the data has not yet been completed. However, it appears that another year or two may be required for the reseeded sites to attain full plant cover development and maximum control of storm runoff and soil stability. When grazing is resumed in the area, portions of each of the paired plots will be protected from grazing by wire cages. These and the grazed sites will be tested by infiltrometers to determine the effects of grazing on their infiltration, surface runoff, and erosion characteristics. These finds will be correlated with information previously obtained from the Area A and B experimental watersheds as a means of determining safe grazing use.

WATERSHED MANAGEMENT

Wind movement has an important effect on evaporation from the land. Atmometer measurements were made under an aspen forest canopy and on an adjacent grassy opening on the Davis County Experimental Watershed during one growing season. This record showed total air movement for the growing season to be 1,799 miles under the aspen and 8,226 miles, or about 4.5 times more in the open. The greatest difference occurred on September 9 when 74 times as much air movement occurred in the open as under the aspen. During the main part of the growing season, the differences averaged about 6.36 times greater in the open. During the early part of the season, prior to full aspen leaf development, air movement in the open was about 1.50 times greater in the open than under the aspen.

The aspen cover caused an average reduction of wind velocity of 2.6 miles per hour and a relative reduction of 79 percent as compared to velocities in the open. The reduction of actual velocities under the aspen tended to be greater during strong than during light winds.

FOREST WILDLIFE RESEARCH

The Fish and Wildlife Service has cooperated with the Experiment Stations in studying the effects of vertebrates on forest and range since 1940. Particular emphasis has been on the effects of the animals on forest regeneration. The main species studied have been white-footed mice, porcupines, snowshoe hares, and white-tailed deer.

White-footed Mice

Since 1948 studies of mouse populations have been made in conjunction with the Station's seed production and germination studies on the Kootenai Forest. It was found that the mice consume about 90 percent of the seed produced each year in that area. Apparently the availability of seed is a limiting factor in the mouse population, since the number of mice has shown the same trend as seed abundance over the past 8 years. Spring and fall censuses of the mice were conducted as usual this year. A new set of census trap lines were established near the mouth of Wolf Creek to test mouse numbers at plots where the State Fish and Game Department had exclosure plots for browse seed trials.

Porcupines

In 1955 the Fish and Wildlife Service supervised a field survey of porcupine damage to ponderosa pine plantations. The survey was financed by Timber Management of Region 1. The survey indicates that only 24.5 percent of the total plantation area is stocked with planted pine trees. About one-sixth of existing planted pine has been killed or injured beyond hope of reaching maturity. The lost and damaged trees have a replacement value well over $50,000 and most of the trees are only now entering the period of greatest susceptibility to porcupine damage. A report is in preparation to be submitted to the Journal of Forestry.

Snowshoe Hares

A study of the life history, ecology, and population dynamics of the snowshoe hare was started in 1951. A population of hares on a 100-acre island in Flathead Lake has been live-trapped each year since 1953. A detailed report is nearing completion and will be submitted to Ecological Monographs during the coming year.

White-tailed Deer

Deer destroy about $90,000 worth of ponderosa pine each year on a single tributary watershed on the Kootenai National Forest. This has been demonstrated by studies in progress since 1946. Exclosure plots built that year contain seedlings in numbers sufficient to successfully restock their areas. Outside the deer exclosure practically all seedlings are eaten by deer. The suggested remedies are increased hunting pressure to reduce deer numbers, and rotational fencing of 160- to 640-acre tracts. At the 1955 hunting season the State Fish and Game Commission increased the hunting harvest by (1) allowing the killing of either sex deer during the entire hunting season, (2) allowing nonresident hunters to buy Montana licenses for $20 instead of the regular $100, (3) allowing each hunter to kill two deer instead of one, (4) extending the hunting season 2 weeks beyond the regular season. The kill was increased fivefold over those of previous years. It is estimated that about half the desired number of deer were harvested.

PUBLICATIONS

A. Departmental publications

EVENDEN, JAMES C., and KENNETH H. WRIGHT. Douglas-fir beetle. U. S. Dept. Agr. Forest Pest Leaflet 5, 4 pp., illus. July 1955.

Leaflet describing features of Douglas-fir beetle development, method of attack, habits, and control.

PLUMMER, A. PERRY, A. C. HULL, JR., GEORGE STEWART, and JOSEPH H. ROBERTSON. Seeding rangelands in Utah, Nevada, southern Idaho, and western Wyoming. U. S. Dept. Agr. Agr. Handb. 71, 73 pp., illus. January 1955.

Instructions on where, how, and what to seed. Includes indicators of site quality, methods of removing competition, methods and seasons of planting, and descriptions of adapted species suitable for various sites from low-elevation salty lands to open subalpine types.

STRUBLE, GEORGE R., and PHILIP C. JOHNSON. The mountain pine beetle. U. S. Dept. Agr. Forest Pest Leaflet 2, 4 pp., illus. June 1955.

Describes history and distribution of species, stages of development, habits, and control.

B. Publications in scientific and professional journals, etc.

ADAMS, LOWELL. Pine squirrels reduce future crops of ponderosa pine cones. Jour. Forestry 53(1): 35. January 1955.

Pine squirrels cut off twigs in winter to eat the cambium. This destroys vegetative buds with their flower anlagen and attached conelets.

ADAMS, LOWELL. A punch-card bibliographic file for vertebrate ecologists. Jour. Wildlife Mangt. 19(4): 472-476. 1955.

The edge-notch type of punch card is used in designing a system for a bibliography. Advantages of the system are (1) for use of individuals or small groups, (2) multiple cross references are possible with a single card per title, (3) cataloguing system can be minutely detailed and can be modified to fit changing needs.

BINGHAM, R. T., and A. E. SQUILLACE. Self-compatibility and effects of self-fertility in western white pine. Forest Science 1(2): 121-129. June 1955.

Cone and seed yields, germinability, and seedling height following self-pollination of 28 trees were compared against corresponding values for cross-pollination. Considerable tree-to-tree variation in self-compatibility and self-fertility was found. "Self-ability" or yield of self-pollinated seedlings relative to yield of cross-pollinated seedlings also varied considerably, averaging about 50 percent for the 28 trees studied. Seedling height during the first, second, and third years, averaged 11, 21, and 21 percent respectively, below heights of cross-pollinated seedlings.

BOE, KENNETH N. A one-foot-square wire seed trap. Jour. Forestry 53(5): 368-369. May 1955.

Describes construction methods and evaluates efficiency of sampling with the small seed trap.

CRADDOCK, GEO. W. Book review: "The Flood Control Controversy," by Luna B. Leopold and Thomas Maddox, Jr. Jour. Range Mangt. 8(4): 183. July 1955.

ELLISON, LINCOLN. Our weight in the balance of nature. Utah Acad. Sci., Arts & Letters Proc. 32: 11-25. 1955.

Balance developed between vegetation and soil during process of primary succession is described for steep mountain slopes, and importance of controlling accelerated erosion, as an ethical as well as a practical element in sound land use, is emphasized.

EVANKO, ANTHONY B., and ROALD A. PETERSON. Comparison of protected and grazed mountain rangelands in southwestern Montana. Ecology 36(1): 71-82. January 1955.

Authors conclude that leaf height, plant area, and yield per unit of plant area of individuals of important forage species--all indicators of vigor--furnish more reliable and usable criteria than cover estimates for evaluating range condition.

FAHNESTOCK, GEORGE R. Cooperative logging slash research in the northern Rocky Mountains. Society of American Foresters Proc. Annual Meeting, 1954.

A description of the cooperative research program of the University of Idaho, U. S. Forest Service, and others, including statement of significant results of the first two year's work.

FRISCHKNECHT, NEIL C., and A. PERRY PLUMMER. A comparison of seeded grasses under grazing and protection on a mountain brush burn. Jour. Range Mangt. 8(4): 170-175, illus. July 1955.

Twenty-two grasses were seeded with smooth brome. After 9 years four rhizomatous species tended to dominate smooth brome under both grazing and protection, three rhizomatous species under grazing but not under protection, and two bunchgrasses under protection but not under grazing. Thirteen species were ultimately suppressed by smooth brome under both conditions. Heavy grazing reduced the yield of seeded grasses and encouraged invasion of sagebrush.

GLEASON, CLARK H., PAUL E. PACKER, and ROY D. HOCKENSMITH. Watershed damage...its signs and causes. American Forests. June 1955.

Describes the kinds of watershed damage that can be caused by fire, overgrazing, poor road building, mining operations, and poor logging practices.

JOHNSON, FRED W., and LOWELL ADAMS. Some lessons from Europe in forest-big game management. Jour. Forestry 53(6): 436-438. June 1955.

In Europe fences are used to exclude herbivores where they are preventing reforestation. Similar measures are suggested for America. Cost analysis indicates this method is economically feasible.

JULANDER, ODELL. Deer and livestock relations in Utah. Utah Acad. Sci., Arts & Letters Proc. 32: 202-203. 1955.

Deer and livestock forage habits and grazing capacity for the different kinds of grazing animals are discussed. It is desirable to graze both deer and livestock in properly balanced numbers to produce maximum numbers of grazing animals and also to maintain a favorable ecological balance in vegetation.

JULANDER, ODELL. Ecology of deer-livestock foothill ranges in Utah. Proc. 34th Ann. Conf. Western Assoc. State Game and Fish Comm., Las Vegas, Nevada, May 1954. 1955.

Drastic ecological changes have been brought about by excessive grazing of sheep, cattle, and deer. Good condition range is compared with those overgrazed by each of these animals and by combinations of deer and livestock.

JULANDER, ODELL. Deer and cattle range relations in Utah. Forest Science 1(2): 130-139, illus. June 1955.

Summarizes foods eaten by deer and cattle on several range types on summer and winter ranges and shows areas of intensive use by deer and by cattle on Oak Creek deer-cattle range. Factors affecting forage competition are outlined and suggestions made for managing big game-livestock ranges.

JULANDER, ODELL. Determining grazing use by cow-chip counts. Jour. Range Mangt. 8(4): 182. July 1955.

On crested wheatgrass pastures, rate of defecation was 11.5 cow chips per cow day. Wide variability of utilization and need for adequate sampling are stressed.

LEAPHART, CHARLES D. Preliminary observations on a current outbreak of western gall rust (*Cronartium coleosporioides*). U. S. Dept. Agr., Plant Disease Reporter 39(4): 314-315. 1955.

Considerable damage in scattered ponderosa pine stands along the Clark Fork River between Missoula and Superior in western Montana is reported. The outbreak has been building up for the past 15 to 20 years; and judging from an analysis of the living galls, shows no signs of abating.

LEAPHART, CHARLES D., and LAKE S. GILL. Lesions associated with pole blight of western white pine. Forest Science 1(3): 232-239, September 1955.

In a study of lesions associated with pole-blighted western white pine trees certain associations with the disease were suggested. A marked reduction in radial growth in the lower stem usually occurs before crown symptoms of the disease appear. The study indicated that reduced radial growth is always associated with pole blight and precedes both crown decline and lesion development. Although lesions are generally associated with pole-blighted trees, they apparently are not directly responsible for the progressive decline of diseased trees.

MARSTON, R. B. Is the world's rainiest rain forest in southern Davis County, Utah? Utah Acad. Sci., Arts, & Letters. 1955.

Compares maximum rates of infiltration of water in an oakbrush patch in Utah with rates reported for a waterspreading project at Seabrook Farms, New Jersey.

MIELKE, JAMES L. Refrigerator storage prolongs aeciospore color and viability. Mycologia 47(1): 149. 1955.

The natural yellow or orange color of fresh, mature aecia, which rapidly fades to a whitish color in a few months at room temperatures, may be prolonged for 2 years or more and viability of the spores greatly lengthened by placing the specimens in paper bags and storing them in a refrigerator at temperatures between 5^{o} - 7^{o} C., (41^{o} - 45^{o} F.). Excellent results have been obtained with four species of rusts: Cronartium filamentosum, C. stalactiforme, C. comandrae, and Peridermium harknessii.

MUEGGLER, W. F., and J. P. BLAISDELL. Effect of seeding rate upon establishment and yield of crested wheatgrass. Jour. Range Mangt. 8(2): 74-76. March 1955.

From seeding crested wheatgrass on the Snake River Plains in southern Idaho at 2, 4, 8, 12, and 24 pounds per acre, it is concluded that all rates will produce satisfactory stands, although longer periods of protection are required to achieve full stands for the lighter than the heavier rates. Heavy seeding is not a cause of stand failure from excessive competition between seedlings, as is sometimes asserted.

NEILS, GEORGE, LOWELL ADAMS, and ROBERT M. BLAIRE. Management of white-tailed deer and ponderosa pine. Proc. 20th North Amer. Wildlife Conf. pp. 539-551. 1955.

Deer destroy all seedling pines that escape other lethal factors on a winter deer range in northwestern Montana. Inside fenced study plots reproduction is adequate. The estimated annual loss is $90,000 on the winter range. Suggested remedies are increased hunter harvest and fencing.

ROE, ARTHUR L. Cutting practices in Montana larch—Douglas-fir. Northwest Science 29(1): 23-34. 1955.

An appraisal of cutting practices in the western larch—Douglas-fir timber type based upon recent studies in western Montana. Shelterwood, seed-tree, and clear cutting systems are compared as to natural regeneration and growth of reserve trees. Adequate larch reproduction can be expected when 40 percent or more of the area is in favorable seedbed and an adequate seed source is present (8 to 10 trees per acre during an average seed year). Net annual growth per acre for the 5-year period following cutting was 51 board feet on the vigor selection shelterwood with a reserve of 18,800 board feet, -437 board feet on the economic selection shelterwood with a reserve of 7,000 board feet, and 9 board feet on the seed-tree cutting with a reserve of 5,400 board feet.

TACKLE, DAVID. A preliminary stand classification for lodgepole pine in the Intermountain region. Jour. Forestry 53(8): 566-569. August 1955.

A classification for lodgepole pine stands based upon age, structure and composition. The principal factors which cause stand variation (elevation, aspect, fire, cutting, insects, disease, wind, snow, and soil) are discussed and stand descriptions are presented. The usefulness and applicability of the classification are described.

C. Processed reports

ANDERSON, I. V. Ponderosa pine tree grades and use for appraisal of timber quality. Mimeo. March 1955.

Describes tentative ponderosa pine tree grades based on observations of growth and lumber yield through the different life stages of the tree and outlines procedures for applying tree grades to stumpage appraisals.

ANDERSON, I. V. Engelmann spruce--its properties, uses, and production. F.P.R.S. 1955.

Describes the broad utility of Engelmann spruce as a commercial softwood and cites the growing demand for this species.

BASILE, JOSEPH V., and RALPH C. HOLMGREN. Artificial revegetation studies on depleted big-game winter ranges in Idaho. Job Completion Reports, Project W 111-R-1. Idaho Fish and Game Dept., mimeo., 23 pp. 1955.

Survey of past field-scale revegetation trials in southwester Idaho; results of seeding tests, evaluating effects of rodents, competition, and time of seeding; mortality due to browsing and trampling by deer; results of depth-of-seeding trials; plans for further browse-revegetation studies.

BEHRE, C. EDWARD, and S. BLAIR HUTCHISON. Future supply and quality of domestic timber. Chapter 6, Timber Resource Review. U. S. Dept. Agr., U. S. Forest Service. 43 pp., illus. 1955. (Preliminary Review Draft)

An analysis of the long-range timber outlook in the United States to the year 2000. Prepared as part of the Forest Service's Timber Resource Review of 1955.

COLE, WALTER E. A method for sampling populations of the pine butterfly, Neophesia menapia (F&F) (Thesis) Colorado A&M College, Fort Collins, Colo. 1955. (In partial fulfillment of the requirements for a Master of Science degree.)

A pine butterfly egg sampling method developed during the 1953-54 epidemic of pine butterfly, for determination of sampling intensities and relating number of eggs per twig with subsequent damage.

COPELAND, OTIS L., JR., and CHARLES D. LEAPHART. Preliminary report on soil-rootlet relationships to pole blight of western white pine. Research Note 22, 6 pp. December 1955.

Results obtained from a study of 6 healthy and 11 diseased 1-acre plots, well distributed throughout the western white pine type, indicate that pole blight is significantly correlated with certain physical soil characteristics and rootlet mortality. These soil factors are effective depth and available water storage capacity, the latter being the most important.

CURTIS, JAMES D. A study of ponderosa pine production in central Idaho. Misc. Pub. 4, 9 pp., illus. June 1955.

Outlines a study designed to test in combination two methods of reproduction, two levels of reserve, logging by two sizes of tractor, in initial stands of low, medium, and high volumes per acre. Also included are a means of sawtimber growth prediction according to treatment, assessment of disturbance of stocking from logging, and plans for gauging the effectiveness of timber stand improvement and regeneration techniques.

CURTIS, JAMES D. Forest management research by the Intermountain and Northern Rocky Mountain Stations. A bibliography, 1912 through 1954. Misc. Pub. 6, 42 pp. December 1955.

Lists the publications of the Forest Management Research Division together with selected works of other divisions considered useful to the student, teacher, and forest manager.

CURTIS, JAMES D. Effects of origin and storage method on the germinative capacity of ponderosa pine seed. Research Note 26, 5 pp. December 1955.

Analysis of viability tests showed that storage method, and to a lesser extent altitudinal location of parent trees, affects the germinative capacity of seed collected from stands in the Boise Basin in central Idaho. After 14 years, seed from young (50-70 years) open grown trees at 5,500 feet and stored at 32° F. had the highest germination (74.7 percent) and seed from scattered old trees (200-350 years)

at the same altitude in above ground cellar had the lowest (44.7 percent). Interaction of variables was significant indicating a difference in germinative capacity for a particular origin depending on the storage method.

DIETERICH, JOHN H., and CHARLES E. HARDY. Rating the 1954 fire season in Region 1 of the Forest Service. Research Note 16, 5 pp. March 1955.

Describes the rating of the severity of the 1954 fire season as measured by burning index and lightning occurrence. Compares the 1954 fire season in the region and on each national forest with the ratings for each year from 1934 through 1953.

DIVISION OF FOREST ECONOMICS. Economics research needs related to wild land management and development in the Mountain States. Research Paper 38, 27 pp., illus. January 1956.

A review of resource problems in the Rocky Mountain States that warrant economic analysis. Covers individual problems in timber, range, water, and wildlife management. Problems in marketing and area management are also covered. Contains a general description of the whole area and briefer descriptions of each problem.

EVANKO, ANTHONY B. Species adaptability and seeding season for increased forage production in northeast Washington. Research Paper 37, 25 pp., illus. February 1955.

Numerous species are rated, on the basis of small plot tests, at three adaptation nurseries, a lodgepole burn, and a logging area. Spring seedings have been more successful than fall seedings.

EVANKO, ANTHONY B. Early spring grazing values for four seeded species on abandoned cropland in northeast Washington. Research Note 18, 4 pp. May 1955.

Intermediate, crested, and pubescent wheatgrasses, and smooth brome, greatly outproduced the weedy vegetation of abandoned cropland. Intermediate wheatgrass was especially early and productive.

FOILES, MARVIN W. Thinning from below in a 60-year-old western white pine stand. Research Note 19, 6 pp. May 1955.

Thirty-year results of one test show that light, moderate, and heavy thinnings all increased diameter growth of dominant and codominant trees. Thinning improved the value by increasing the proportion of high-value white pine. Volume growth following light thinnings was about the same as for the uncut stand. The heavy thinning reduced volume growth.

GRAHAM, DONALD P. Distribution of pole blight of western white pine. Research Note 15, 3 pp. March 1955.

Disease surveys conducted in 1953 and 1954 reveal only minor extensions of pole blight beyond the previously known range. The acreage of western white pine affected by pole blight is now estimated to be between 90,000 and 95,000 acres of moderate to severe damage. There is an undetermined acreage with scattered pole blight trees where damage may later become appreciable.

HARDY, CHARLES E., CHARLES E. SYVERSON, and JOHN H. DIETERICH. Fire-Weather and Fire-Danger Station Handbook. Misc. Pub. 3, 84 pp., illus. April 1955.

A comprehensive guide outlining methods for locating, equipping, operating, inspecting and using fire-weather and fire-danger stations. Contains complete information on fire-weather instruments. Includes sections on cloud identification and burning index rating. This handbook is the standard guide for forest fire-danger rating activities in the Intermountain West.

HERRINGTON, ROSCOE B. Montana Christmas tree shipments reach record high. Research Note 17, 5 pp. April 1955.

Numbers of Christmas trees shipped from various Montana counties by rail and truck, and numbers shipped to most important state markets.

HERRINGTON, ROSCOE B. Northern Rocky Mountain pole production in 1954. Research Note 24, 4 pp. December 1955.

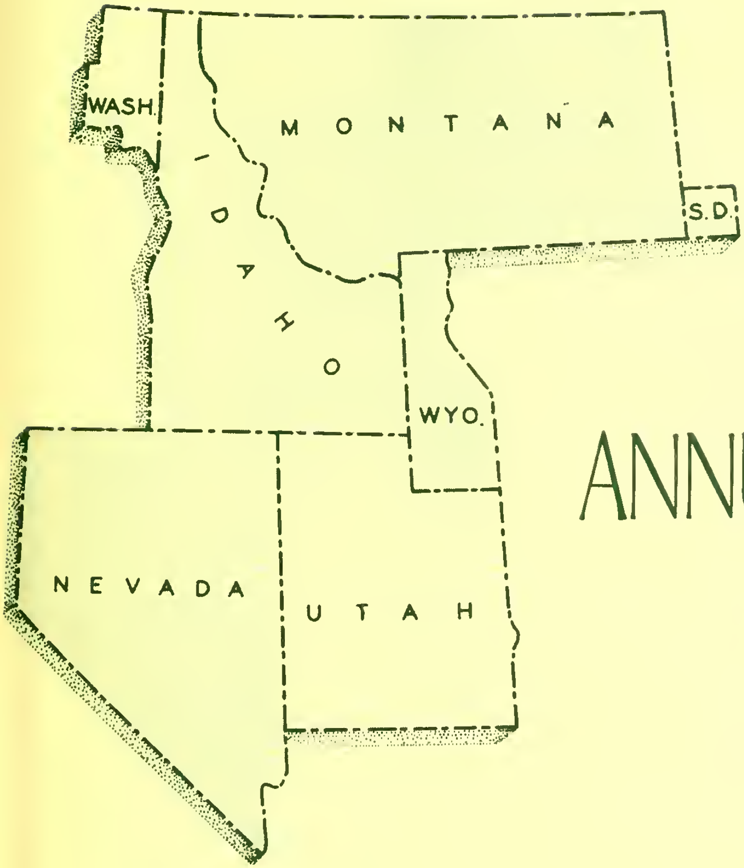
Numbers of poles produced in 1954 in Montana, north Idaho, and northeast Washington. Production by species and source is also given. Proportions by length and A.S.A. class are shown.

KECK, WENDELL M. The Forest Service answer to "Why Study English?" Mimeo. January 1956.

"The magic of words lies in the power they have, when properly chosen and arranged, to convey to other people what we wish them to know what is in our minds."

LAMMI, J. O. Statistics on western wild land resources. Research Paper 31 (Rev.), 24 pp. July 1955.

A collection from numerous sources of available statistics on wild land resources in Regions 1 and 4 of the Forest Service. Contains data on water, timber, recreation, wildlife, livestock, and land and population.



ANNUAL REPORT 1956

INTERMOUNTAIN FOREST & RANGE EXPERIMENT STATION

FOREST SERVICE
U. S. DEPARTMENT OF AGRICULTURE

OGDEN, UTAH

REED W. BAILEY
DIRECTOR

STRENGTHENING THE RESEARCH EFFORT

In introducing the annual report of the Intermountain Forest and Range Experiment Station for 1955, the Golden Anniversary of the Forest Service, major problems and opportunities in the next 50 years of forestry were noted. It had been a year of taking stock and of establishing goals for the future. A concluding statement read: "Although the general goals of wild land management have become clear, many methods and procedures, principles, and concepts must be worked out by the scientific method before these goals can be reached." The stage was set for a critical review of our research organization. How well equipped were we to carry on the research program needed to meet our goals? Just where was our investigative effort most deficient and what spots were most in need of strengthening?

In 1956, the first year of the second half-century of Forest Service activity, the Department of Agriculture launched most appropriately a study of the program of each of its research agencies. An integral part of the review was the preparation of a 10-year plan of increased effort to meet adequately the most pressing needs for research. This Station prepared, as its part of the project, an analysis of the most urgent forest land problems of its area and outlined a program to cope with them. As a sequel to last year's "look ahead" in terms of expected progress and future goals, it seems desirable to sketch here very briefly some of the outstanding elements in a program designed to make the first decade of the second 50 years a period of notable progress.

A number of our major forest land problems cut across all or many of our research divisions. One logical way, therefore, to classify research program deficiencies in this category is by vegetative cover type. Using this approach the major resource management needs in the Intermountain Station area may be arrayed as follows:

Guides for wise use of ponderosa pine lands.

Understanding the proper relationship of grazing use, erosion control, and water yield of mountain herblands.

Better management of western white pine and associated species.

Management and utilization of Intermountain lodgepole pine.

Erosion control and forage improvement on sagebrush-juniper range.

Improved guides for western larch--Douglas-fir management.

Protection and management of interior Douglas-fir.

Learn the silviculture and protection of Engelmann spruce-subalpine fir.

Restoration of east Sierra pine-brushlands.

Management of mountain brush.

Grazing management of cheatgrass.

Management of aspen-fir.

Grazing management and erosion control of salt-desert shrub.

Erosion control and forage production in southern desert shrub.

In the case of some of the above needs substantial research is now under way, while in others virtually nothing is being done. But regardless of the present level of activity and accomplishment, a greater research effort is required right down the line.

In strengthening to meet these 14 major cover type problems, what are the particular areas of research towards which each of our resource management divisions should direct its special efforts?

In Forest Management Research increased emphasis must be placed on establishing new forests of better quality through natural regeneration, planting, and genetical improvement as virgin stands are cut over. More effort must be directed towards developing proper management practices for existing young stands. Old-growth forests are important and should be given continuing study, but to meet the "goals of tomorrow" more research effort must go into the "trees and stands of tomorrow." The many mensurational needs deserve prompt attention and more basic silvical studies must be provided.

Range Management Research must devote more attention to game-habitat investigations and to developing a greater understanding of the ecological basis for using and maintaining grazing lands. It should devise ways and means to restore grass and herbaceous cover to denuded ranges, to increase forage productivity, to lessen the dominance and spread of undesirable species, and to obtain maximum use consistent with control of erosion.

Watershed Management Research must redouble its efforts to learn how to reduce sediment production and increase water yield. More specifically it must determine how to minimize summer floods from torrential rains and winter snow melt floods; measure water use by different cover types; develop methods of maintaining the stability of loose soil on steep slopes under the impact of logging and grazing disturbance; and strengthen its watershed studies to evaluate the effect of different productive, protective, and corrective treatments.

Forest Utilization Research must give more emphasis to new and enlarged uses for Intermountain tree species. One promising field lies in the more complete utilization of forest and plant residues. It must concentrate greater effort on developing adequate harvesting methods for Intermountain forests, particularly for stands growing on steep, erosive slopes. The Station should do more than it is in evaluating existing log and tree grades and in providing leadership for their further expansion and use.

Throughout all the Intermountain forest types Forest Fire Research should strengthen its endeavors on logging slash control, general fire hazard reduction measures, fire prevention, studies of fire effects, and fire suppression methods. It must play a leading role, also, in developing techniques for the prescribed use of fire in forest management.

Insects are a serious concern to forest managers in the Intermountain Station area. Forest Insect Research must enlarge its studies of the ecological relationships and factors affecting the rise and fall of epidemic populations of such insects as the Black Hills beetle, mountain pine beetle, spruce budworm, and Douglas-fir beetle. With regeneration such a critical factor in forest management in the area and treatment of young stands becoming so important, studies of the pine engraver beetles which attack seedlings, saplings, and poles, and insects which damage cones and seed must be undertaken. The ultimate goal is the substitution of biological and silvicultural control for the more costly direct control measures.

Losses to forest diseases are very heavy in both the Northern and Intermountain Regions, but disease surveys must be strengthened considerably in order to assess such losses properly. Forest Disease Research should devote much greater effort in particular to the dwarfmistletoes, needle blights, pole blight and blister rust of western white pine, and a number of other pine rusts.

Some of the most highly specialized research needs lie in the field of forest protection. Because of the extensive forests in the Intermountain Station area and the tremendous distances between them, it is imperative that better insect and disease survey methods be developed to insure maximum coverage with minimum effort. Specialized needs in fire research are so numerous that they cannot even be enumerated here. One of the most spectacular and deserving projects, however, is that of weather modification, in which possibilities of preventing or reducing the severity of lightning fires are being tested. This and other urgent fire, insect, and disease problems require special laboratory facilities for effective study. A forest fire research laboratory at Missoula,Montana for basic studies of atmosphere, fuels, and model fires and for developing and testing methods, techniques, instruments, and equipment would greatly increase the effectiveness of this phase of the Station's program.

Forest Economics must provide the analyses to determine how far forest managers are justified in going to obtain regeneration, what intensity of protection against fire, insects, and disease is practicable, and which harvesting and cultural systems are most profitable. Economic analyses are needed, as well, to weigh the costs of special range and watershed treatments against the values to be derived. Economic studies to facilitate sound industrial expansion are urgently required now that the timber resources of the Intermountain Station area are being tapped more and more heavily. Forest products marketing research is an accompanying need.

A final and very special word should be said for the Forest Survey. Wise management of our forest resource depends in large part upon the accurate knowledge of its extent and condition which can come only from a sound inventory. To secure this vital information more quickly, we must step up the development of aerial photo interpretation, forest inventory techniques, and aerial photo coverage, and speed up the actual measurement of samples. The pressure of industrial development demands that reliable information on our forest resource become available in the near future. The Forest Survey must be expedited.

In preceding paragraphs some of the more noteworthy problems and needs for future research have been portrayed. It is well to look ahead, to analyze requirements and opportunities in the years to come, to establish goals, and to outline the measures necessary to attain them. Planning for the future, however, has little substance unless accompanied by sound and substantial current accomplishment. That progress was made on a number of Intermountain fronts during 1956 is illustrated by the divisional statements which follow in this report.

FOREST MANAGEMENT RESEARCH

In the area served by the Intermountain Forest and Range Experiment Station, as in other parts of the country, early efforts in Forest Management Research were directed at old-growth forests. Their high value and overmaturity attracted the research forester to them just as surely as they drew the logger and forest industry. The primary need was to develop methods of harvest cutting which would remove the crop economically, secure adequate, desirable reproduction, and satisfy the other requirements of good silviculture, and still meet the demands for forest products over a period long enough for young stands to reach merchantability. It was a large order that has in the past commanded the major attention of Forest Management Research and will continue to hold a vital place in the Station's program for some time to come. Much of the knowledge gained from studying old-growth stands will apply, also, to young stands as they reach maturity.

But important as the old-growth forests may be, the real future of forestry lies in establishing new stands promptly after harvest cutting and providing for their maximum development, in restoring to productivity forest lands lost in the past due to fire, insects, disease, and brush invasion, and from improving tree quality through genetics. As rapidly as it can be accomplished without loss of value from established experiments, Forest Management Research is moving its emphasis to studies of reproduction and young stands. A greater proportion of effort is now going to research projects involving basic tree studies, regeneration (establishing new forests by natural or artificial means), intermediate cuttings (cultural measures in young stands), and genetics (improvement of trees and stands by selection and breeding). It is a logical development as forestry in the United States moves from its early exploitative phase into the intensive management of young, growing forests.

We are indicating the shift in emphasis that is taking place by the statements of accomplishment highlighted in the Forest Management Research section of this report. All of the items which follow were selected from the fields of regeneration, managing young stands, and genetics, although most of our effort is still with old-growth stands.

REGENERATION

Shade is Beneficial to Engelmann Spruce Initial Seedling Survival

Recent cuttings in the Engelmann spruce type to control the Engelmann spruce beetle have opened up many stands in the northern Rocky Mountains. Some of the areas on which clear cutting was imperative are not reproducing satisfactorily despite good seed years in 1952 and 1954. Special measures such as scarification with brush blades on bulldozers and prescribed burning have been taken to provide bare mineral soil seedbed and reduce competition by low vegetation. Also, seed trees have been left wherever possible either on the cut-over areas or as surrounding uncut timber. Large numbers of new seedlings have appeared in the spring but very heavy mortality has taken place in mid- and late summer, particularly on the clear-cut areas. A study of first-year seedling survival shows that insolation, even on north and east slopes of moderate gradient (19-28 percent) is an important cause of seedling loss which can be reduced by shading the seedbed.

Seedling mortality and survival were observed under several treatments in an effort to determine the causes of loss. The treatments were:

1. Shading (about 50 percent shade provided with laths)

2. Watering (during the critical season to prevent drought. Soil samples taken at weekly to 10-day intervals showed adequate soil moisture in the top 3 inches of soil all summer, so heavy watering was not necessary.)

3. Weeding (periodic removal of invading vegetation)

4. Control (seeded but nothing else)

All plots were seeded immediately following the disappearance of snow on scarified seedbed and mortality was observed and recorded at frequent intervals. Maximum soil surface temperature was determined by means of "tempils®" (wax pellets made to melt at different temperatures).

High soil surface temperature which resulted in heat girdling of seedlings proved to be the greatest single cause of seedling mortality, accounting for from one-quarter to two-thirds of total mortality. Soil movement resulting from high-intensity summer rains was next in importance, causing seedling loss by washing seedlings out of the ground where soil was eroded and smothering seedlings where soil was deposited. Cattle trampling and drought loss followed soil movement in importance.

The principal benefit of shading resulted from reducing heat girdling, most of which occurred from about mid-July to the first part of August. During that period a considerable portion of the seedbed surface frequently reached or exceeded the lethal temperature (approximately 130° F.) for spruce seedlings. Beneath the lath shades the duration of the high lethal surface temperature was brief on any given spot. The high soil surface temperatures on unshaded plots were maintained for much longer periods of time causing more mortality from heat girdling.

Shade had no noticeable effect upon drought losses, most of which occurred where the seedling roots penetrated small pieces of rotten wood and debris beneath the soil surface and where the root penetration was interrupted by rocks close to the soil surface. Seedling root penetration averaged less than 3 inches during the first growing season. Differences in soil moisture in the top 3 inches of soil on the shaded and unshaded seedbed were insignificant because of frequent and well-distributed summer rains (4.72 inches between June 12 and September 9). If the soil moisture situation had been more critical, shading might have caused differences in drought loss.

Weeding or the removal of competition had no significant effect upon survival. Here also the effect of competition might have been more noticeable if the soil moisture situation had been more critical.

The micro-climate on seedbeds in spruce clear cuttings is severe and this study, although inconclusive, does point out the need for shade in seedling survival. To provide the needed shade in regeneration cuttings it may be necessary to keep clear cuttings small enough for shading from the side, to practice strip cutting oriented in an easterly and westerly direction, or to leave some slash and debris on the ground.

Regeneration Studies at Boise Basin Experimental Forest

Studies in artificial regeneration of ponderosa pine on the Boise Basin Experimental Forest were pursued vigorously during the year. To supplement the Town Creek planting (described in the Station's annual report for 1954) a small test was made on the Headquarters site of the experimental forest. Two types of mulching (sawdust and pie plates), with half of each area sprayed to knock down competing vegetation, and planting holes dug by a power saw with post-hole drill attachment have proved successful so far. The power auger produces holes deep enough for proper planting of trees with long roots (over 14 inches) and is fast and easy to use. Two hundred holes per hour can be dug with it. Careful tamping was found to be a requisite for high survival.

After earlier preliminary trials, several kinds and sizes of paper containers are being used in quantity to test the usefulness of container planting on severe sites. The plan is to set out in the field both container and seedling, thus avoiding disturbing the roots. Perhaps by insuring quick deep penetration of the taproot, mortality due to lack of moisture and insolation may be avoided. A special rodent- and bird-proof shelter with watering facilities was constructed for the purpose of raising the seedlings in containers. No outplanting was done in 1956, but it is planned to continue the project during the coming year.

Red Squirrels Cause Ponderosa Pine Cone Loss

During the year a study of the impact of red squirrels on ponderosa pine seed crops was completed on the Kootenai National Forest in northwestern Montana. Four successive cone crops were studied by climbing eight mature ponderosa pine trees three to five times a year[1/] and noting the number of cones cut by squirrels. Records were also kept of other factors causing mortality of cones. In the course of the study, the development of 1,109 female flowerbuds was followed. The four cone crops from 1953 to 1956 were rated either poor or fair. No good or excellent crops occurred during these years.

Red squirrels cut from 30 to 98 percent of the ponderosa pine cones maturing annually, or an average of 66 percent of the maturing cones in four successive cone crops. Additional mortality was sustained each year prior to the period of cone ripening by the loss of 1-year-old conelets incidental to the cutting of branches with mature cones and the cutting of branches without mature cones.

Considering all causes of mortality from flowerbud formation to cone maturation, red squirrels account for a much lower percentage of cone loss. This is so because of heavy first-year loss, principally through abortions, and also because of the relatively small amount of cutting when cones are in the immature or conelet stage (the first year and early part of the second growing season).

Controlling Squirrel Damage to Ponderosa Pine Cone Crops

Cone and branch cutting on conifers by tree-climbing squirrels occurs in many forest regions throughout the country. In western Montana the red squirrel /(*Tamiasciurus hudsonicus richardsoni*) (Bachman)/ is the only known species that cuts seed cones and branches of ponderosa pine. Attempts by foresters to obtain

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1/ The number of trees was reduced to six for the 1956 cone crop.

successful natural reproduction of ponderosa pine continue to be hampered by these animals, especially during the years of poor to fair seed crops. That the cone cutting reaches substantial proportions has been shown in the preceding item.

A promising method for controlling tree climbing and seed cone destruction by red squirrels has been developed and tested by the Intermountain Station. A sheet of smooth aluminum 18 inches wide, nailed in a continuous band around the trunks of isolated ponderosa pine trees, at a height of 5 to 7 feet above the ground, prevented squirrels from climbing. In the same test, bands 12 inches or less wide were ineffective.

Preventing squirrels from climbing seed trees, however, is only part of the problem. Squirrels can jump into the crowns of trees protected with bands from nearby unbanded trees. To determine how far these animals are able to jump when foraging for food under natural conditions, different "crown isolation" distances were tested.

It was found that 5.3 feet of "crown isolation" prevented squirrels from jumping from unprotected (unbanded) to protected (banded) trees. However, since squirrels under escape conditions have been observed to jump 7 feet horizontally and to span 10 feet in a diagonal jump with a drop of 12 feet, further tests are planned. Under normal conditions, 7 to 8 feet of isolation should give a high degree of protection.

Further studies are planned, also, to investigate possibilities of reducing the cost of banding by the use of cheaper material than aluminum and by faster methods of band attachment to the trees.

Young Ponderosa Pine Trees Show Best Response to Seed Production Stimulation Measures

A small test of methods of stimulating seed production in Montana trees of all ages showed some response to stimulation in the first crop developed since treatment. Moreover, the data indicate that young trees which might not have produced a crop were stimulated to produce quite a few cones. Table 1 gives the results on Keen age class I, II, and III trees for partial girdling and on young trees for the continuous knife-cut girdle.

Table 1.--Total number of mature cones by age classes and treatment[1/]

Keen age class	Partial girdle		Knife-cut continuous girdle	
	Treated	Check	Treated	Check
	Number	Number	Number	Number
I (50 years)	108	1	106	4
II (140 years)	365	316	-	-
III (220 years)	633	380	-	-

1/ Based on 5 trees in each category.

Treatments were applied during late summer in 1954. The partial girdling was accomplished by removing a 1- to 2-inch-wide strip of bark around the tree except for a 4-inch bridge which was left intact. The continuous knife-cut girdle consisted of making a single knife cut through the bark and cambium completely encircling the tree.

While the continuous knife-cut girdle was applied only in the young age class (Keen age I trees), the results in that age class are similar to those in the comparable age class treated by the partial girdling method (table 1).

Tree vigor was not impaired seriously by girdling. In 1956, 2 years after treatment, only two trees, one Keen age II and one Keen age III, showed slight yellowing of the foliage. All the other trees remained healthy.

Further tests are needed to determine the response of older trees in a year of poor cone production.

Results From Thinning Seed Spots

Sowing 5 to 25 tree seeds in small prepared spots often results in several seedlings becoming established. Tests of thinning seed spots were made in northern Idaho to determine the effect of density on height and diameter growth of the dominant seedlings. Spots sown to western white pine, ponderosa pine, and Engelmann spruce were included in the tests.

Nine-year results reported in 1948 showed that the number of seedlings per spot had little effect on height growth of seed spot dominants for any of the species tested. Heights of dominant seedlings of white pine and spruce increased very slightly with increase in number of seedlings per spot. Ponderosa pine showed a slight reverse trend. Diameter 1 inch above the ground line decreased for all species as numbers of seedlings per spot increased.

Additional observations made 16 years after sowing show that density has had a slight effect on height growth and a marked effect on diameter growth of dominant seedlings of all species tested. Both height and diameter growth have decreased as density increased. The effect on height growth of white pine and spruce is a reversal of earlier results while the effect on diameter growth is more striking than at the time of the 9-year analysis.

Survival of White Pine Planting Stock in Grass-Sod

In the summer of 1954 the Development and Improvement Unit of Blister Rust Control tested the effect of five concentrations of Dalapon (2,2-dichloropropionic acid) spray on grass-sod and accompanying forbs and herbs. The Inland Empire Research Center cooperated with the Blister Rust Control unit to test survival of trees planted in the varying densities of grass-sod which resulted. Western white pine planting stock, 2-2, was used for the test in which 100 trees were planted in each of 12 plots (two plots of each of six spray treatments).

Results of the first year survival show no distinct relationship between survival and sod density. Survival at this stage of the experiment seems to be related to plot location, indicating a possible site difference which partially offset the effect of sod density. Later measurements may clarify the effect of grass-sod density on survival of the planted trees.

Region 4--Intermountain Station
Cooperative Studies

As agreed early in the year with National Forest Administration in Region 4 and as discussed in some detail in a timber management meeting of research, regional office, and national forest representatives, cooperative studies were initiated on six national forests during the year. Visits were made to the Boise, Payette, Targhee, Bridger, Uinta, and Dixie National Forests to examine problems, mostly of regeneration, on the ground and suggest either procedures for overcoming the difficulties or tests to determine a specific technique which would achieve a solution. Problems are evident in the ponderosa pine, Engelmann spruce-fir, lodgepole pine, Douglas-fir, and aspen types.

With regard to ponderosa pine, the success of the Town Creek planting project, which Research and National Forest Administration designed jointly, and the more recent good survival in plantations using Town Creek methods of stripping brush and planting in plowed rows together with careful handling of planting stock, have been heartening. Successful planting on the more severe sites still remains a major difficulty, however.

In the Engelmann spruce-fir type, it seems to be a question of cutting to create openings by groups or strips and scarifying the soil to induce natural regeneration. This is not always easy by virtue of steep topography or the presence of many boulders, but more commonly because most of the current spruce cutting has had to be in salvage operations of insect-killed timber which are not generally conducive to regeneration. Furthermore, the surface soil horizons sometimes dry out even where summer precipitation is generally common and heavy mortality of seedlings results, as occurred this year on the Aquarius Plateau of the Dixie National Forest.

Douglas-fir regeneration is mysteriously absent on certain areas. Careful examination has revealed no obvious reason for this deficiency but plans for testing of seed for viability and for trials of several cutting methods have been made in an attempt to learn the causes of this shortcoming and establish a successful technique.

Lodgepole pine cuttings have not always met with the same success of regeneration establishment as similar cuttings in Region 1. Insufficient scarification may be the chief cause. In a new sale on the Bridger National Forest it is planned to cut lodgepole pine in strips with various treatments of slash and several sources of seed for regeneration.

Aspen sales have increased sharply in the last year or so and at least four forests in Utah had sawlog sales in addition to cordage for excelsior. Aspen, regardless of age, will reproduce by root suckering but must be protected from browsing and plans are being laid to study the regeneration of the species by rotation of cutting and grazing areas. Because little is known on the subject in this region, there is a fine opportunity in these sales to test regeneration techniques and postlogging stand and young stand treatments.

Engelmann spruce seed lots from southern Utah were tested for viability and showed wide variation. Further tests of seed from Idaho, Wyoming, and Utah will be made in the early spring of 1957.

MANAGING YOUNG STANDS

Cleaning Western White Pine

Results from two sets of tests established in 1935 in Idaho on the Deception Creek Experimental Forest and on the Kaniksu National Forest show what can be expected from various types of cleaning and suggest possible improvements in the technique and scheduling of cleaning operations. In both cases an initial investment of 1 to 2 man-days per acre has resulted in greatly improved composition after 20 years. Additional benefits have been gained in the form of larger crop trees.

In the Deception Creek study a 16-year-old stand composed primarily of grand fir, western hemlock, and western white pine was weeded to form a nearly pure white pine stand. Less desirable species were left when no white pine trees were available. The test consists of three blocks of three plots each (two cleaned and one uncleaned). All cleaned plots were treated alike.

The dominant and codominant stand on the cleaned plots 20 years after weeding averaged 78 percent white pine compared with 23 percent white pine on the check plots, or a three-fold increase in the percentage of potential white pine crop trees as a result of the cleaning operation. The proportion of white pine in the complete set of plots would have been much greater had it not been for poor initial white pine stocking on one of the replications at the outset of the study. Here other species were substituted for pine in the selection of crop trees.

In addition to greatly improved composition, the cleaning has resulted in an increase in the size of the dominant and codominant trees. The average diameter of cleaned white pine dominants and codominants 20 years after weeding was 5.1 inches compared with 4.0 inches on the check plots. Dominant white pine on the cleaned areas averaged 4 feet taller than on the uncleaned areas.

The volume in dominant white pines on the weeded area accounted for 95 percent of the cubic foot volume of the dominant stand. On the check area, dominant white pines made up only one-fourth of the cubic volume of the dominant stand. The total volume of the dominant stand, including all species, was no greater on the cleaned areas, however. Considering all crown classes and all species, the check areas had 12 percent more cubic foot volume than did the weeded areas.

The Kaniksu plots, located in the Upper West Branch drainage of Priest River, test the development of white pine when released from a competing stand composed primarily of fast growing,

intolerant western larch and lodgepole pine. Established when the stand was 8 years old, the test consists of three 0.4-acre plots each treated as follows:

Heavy cleaning--all trees except white pine and western red-cedar were cut.

Moderate cleaning--all white pine and cedar were left. Larch within 8 feet of white pine trees were removed and Engelmann spruce and Douglas-fir were cut only when crowding white pine. When pine was absent, smaller larches were left and given an 8-foot spacing.

Check--left uncleaned.

The stand below 0.5 foot in height was not considered in the cleaning operation. Many small larches were left which subsequently outgrew the released white pine and reduced the effect of the cleaning operation, especially in the moderate cleaning. Nevertheless the white pine had fewer larches with which to compete.

Twenty years after treatment the percentage of white pine in the dominant crown classes was directly proportional to the degree to which the stands were cleaned. Less than 1 percent of the dominant trees on the untreated area was white pine as compared to 30 percent on the moderate cleaning and 61 percent on the heavily weeded plot. Although white pine was placed in a completely dominant position by the heavy weeding it gave up 40 percent of this advantage to larch and lodgepole pine in the 20 years after weeding. Most of this loss occurred during the first 5 years following weeding and could have been corrected at little additional cost by a followup cleaning.

Diameter and height of the dominants varied with degree of cleaning, also. Moderately cleaned white pine dominants averaged 4.2 inches in diameter and 29 feet in height, while unweeded dominants had an average diameter of 2.5 inches and an average height of 17 feet. Heavy cleaning increased the diameters to 4.6 inches and the height to 31 feet. On a percentage basis, heavy cleaning increased diameter of white pine dominants by 185 percent and height by 182 percent.

Timber Stand Improvement on Boise Basin Experimental Forest

As a followup to the Ponderosa Pine Production Study, a major project reported in the last several annual reports, timber stand improvement work was begun on the sale area in 1956. The working plan provides for thinning, pruning, and improvement cutting in sapling and pole stands. During the period July 5 to September 28, two compartments and most of a third were thinned according to plan. Costs of various phases of the project were kept.

In conjunction with the stand improvement project, experimental plots are being established in each thinned compartment. Six plots to give detailed information on growth and yield were laid out and measured in 1956; the study plan calls for two plots in each compartment treated.

In cooperation with the Boise National Forest, slash from the thinnings was reduced in one compartment by the use of a chipper mounted on a D-7 tractor. Good disposal was secured, but the cost of chipping proved to be high.

For demonstration purposes two 1/5-acre plots in a 1935 plantation near the experimental forest headquarters were thinned in September by the crown method. Crop trees were pruned. In their 21 years of growth, the trees on the plots reached sufficient size and density for effective thinning and pruning.

This project will be continued next year.

Three Tests of Precommercial Thinnings in Ponderosa Pine Stands

Three operations during the period 1933 to 1935 demonstrate what may be accomplished by thinning dense young stands of ponderosa pine in western Montana. Two locations and three average site and age classes were represented. The stands were thinned from below, removing suppressed trees and trees of poor form first. An unthinned check plot was reserved for each site class.

Twenty years after thinning, gross cubic-foot increment of the thinned plots exceeded that of the unthinned plots on all but the best site (site index 70). Had the check plot for this best site series been of more nearly normal density, these thinned plots might also have exceeded the unthinned check. Between degrees of thinning, both gross and net cubic-foot volume growth subsequent to thinning were not related to density within the range tested.

Trees which would have been left had the check plots been thinned were so designated on the plot records. The increase following thinning in cubic-foot volumes for comparable portions of the stands are shown in table 2. Similar trees in thinned stands grew from 135 to 317 percent more rapidly than did those on check areas. A similar comparison of diameter growths shows that much of this increased growth is the result of release of codominant crown-class trees.

Table 2.--Growth of comparable trees in thinned and unthinned ponderosa pine stands

Site index	Degree of thinning	20-year net increment after thinning	Cubic foot increment compared to unthinned plot
		Cubic feet	Percent
70	Heavy	1,453	135
61	Heavy	1,604	317
	Moderate	1,672	280
44	Heavy	900	187
	Light	900	138

These tests suggest that precommercial thinnings of ponderosa pine may possibly increase gross production in stands near normal density, materially increase diameter growth of dominant and codominant trees, and concentrate the productivity of the site on trees which will comprise the future merchantable stand.

Commercial Thinnings on Woodlots in Second-Growth Ponderosa Pine

Five-year results from three tests of commercial thinning of sawlog material in 90- to 100-year-old ponderosa pine stands in the Inland Empire confirm at least in part the results reported last year from a comparable test. They also emphasize the fact that mortality, for the most part caused directly or indirectly by logging, often reduces at least temporarily the benefits of thinning.

Two of the tests, conducted near Usk and Colbert, Washington, confirm that light thinning, removing about 30 percent of the volume, improves the quality of the growing stock without sacrificing gross growth. In both tests net growth following light thinning was less than that of the unthinned stand because of greater mortality. Most of that mortality resulted from trees

knocked over or broken off during logging and from bark beetles which thrived and increased in logging slash and trees weakened by logging damage. Mortality caused by logging usually is temporary, so that in the future, the thinned stands should retain a larger share of the gross growth.

Growth of the heavily thinned stands, from which 75 to 80 percent of the volume was removed, was considerably less than that of either the lightly thinned or unthinned stands.

Results from the third test, located near Tensed, Idaho, are incomplete since cutting was not finished in the stand marked for light thinning. However, growth data from that test were included in the analysis to permit comparison of heavily thinned and unthinned stands and to show the high growth rates that are possible on excellent ponderosa pine sites such as the one on which this test was located. Despite an average annual mortality of 292 board feet per acre, net growth averaged 408 board feet per acre per year. The Usk and Colbert tests were located on sites rated good and poor respectively.

GENETICS

Breeding Blister Rust-Resistant Western White Pine of Good Growth and Quality

The development of a blister rust-resistant western white pine is a joint project between Blister Rust Control, Region 1, and the Intermountain Station. Rust resistance aspects are the responsibility of Blister Rust Control. Major accomplishments in the vigor-quality phases which are a part of the Station's research program are described briefly below.

An intensive search during 1956 resulted in 123 new selections apparently resistant to blister rust, which make a total of 195 selections now available for study. Wind pollinated seeds were collected from as many of the new selections as possible and will be used for making a preliminary evaluation of both rust resistance and inherent growth capacity.

Routine measurements of growth rates of progenies were continued. The large amount of data being accumulated on growth of progenies up to 5 years of age and of their parents will soon permit an intensive study of the inheritance of this trait. Crown form data are likewise being accumulated. Recent developments include the use of current growth rather than total height in assessing juvenile growth in progenies up to 4 years of age. This seems to eliminate the need for seed weight adjustments in progenies

beyond 1 year of age. The possible use of length of epicotyl (the portion of stem above the cotyledons) instead of total height in assessing growth rate of 1-year-old progenies is also being investigated.

A new flower induction test was installed this year in cooperation with the Pacific Northwest Station. Its purpose is to learn whether flowers can be obtained earlier on material grown on the northwest coast than in northern Idaho. Cones were found on trees as young as 7 years in that area. Such early flowering may be due to the longer growing season or to the occurrence of an early flowering race. The test involves grafting of seedlings into the tops of 10-year-old trees and planting as controls seedlings of the same northern Idaho origin in both localities. About 90 percent of the grafts were successful at the end of the first season and all planted seedlings survived to that time.

Physiological tests designed to aid in assessing inherent growth rate or other traits in the juvenile stage were continued. Preliminary results of a foliage dry matter content study showed that progenies of trees growing at a high elevation had more dry matter content (measured in early spring) than those of parents at lower elevations. Seed osmotic pressure tests, the possible utility of which was reported last year, are also being continued.

A report summarizing evidences of local ecotypes has been prepared for publication. It contains information obtained on juvenile growth rates, seed osmotic pressure, and to a lesser extent on foliage dry matter content of a large number of progenies of parents growing on different sites. Progenies of trees from better sites (moist, low elevations) usually grew more rapidly in early life when planted on good sites, and exhibited lower apparent seed osmotic pressures than those of trees on poorer sites (dry slopes or high elevations). Progenies of parents at high elevations had more foliage dry matter content and grew more rapidly when outplanted at high elevations than progenies of low elevation sources.

Lodgepole Pine Hybrid Interplanting

A study designed to test and demonstrate interplanting as a practical method of the conservative use of hybrid stock was started in 1952. Five-year results show that the survival of hybrids[2/] (*P. contorta* x *P. banksiana*) from a California seed

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2/ The hybrids were developed by personnel from the Institute of Forest Genetics, Placerville, California, a branch of the California Forest and Range Experiment Station.

source was 37 percent, and of indigenous nonhybrid lodgepole pine only 21 percent. Both rates of survival are below an amount satisfactory for successful plantation establishment without excessive fill-in planting.

Height growth was also studied. Comparative heights 5 years after planting are as follows:

	Average total height 1/	Average maximum height 2/	Range of heights
	Feet	Feet	Feet
Hybrids	.67	1.1	.3 to 1.4
Nonhybrids	.56	.8	.2 to .9

1/ Basis - 25 undamaged trees; difference not statistically significant.

2/ Basis - tallest 5 trees; difference significant at the 1-percent level.

Although survival is low the study will remain active and the trees will be examined at the end of 10 years to see if present differences in survival and growth rate are maintained.

FOREST DISEASE RESEARCH

In introducing the following statements of progress in Forest Disease Research at Intermountain Forest and Range Experiment Station during 1956, it seems appropriate to say a special word concerning forest disease surveys. While not as well publicized or understood as other disease projects, they are vitally important. Surveys are essential to learn what diseases are present in the Intermountain area and something of their importance, to detect the presence of new threats, to appraise the extent and damage of known diseases for research planning purposes, and to delimit outbreak areas for control purposes. They are a necessary prerequisite to a comprehensive research program pointed at the forest diseases of highest priority.

Despite their importance, no forest disease survey has ever been conducted in Region 4 (the Intermountain Region). They are very deficient in Region 1 (the Northern Region), with a reasonably complete inventory of disease losses or conditions available only for pole blight and blister rust of western white pine. In any expansion of forest disease research activities, there should be provision for adequate surveys. Limited progress in this direction was made at Intermountain Station in 1956 by starting forest disease surveys of the dwarfmistletoes in Region 1.

Forest disease survey accomplishments as well as highlights of the Station's work with other disease problems during the past year are given in succeeding paragraphs.

FOREST DISEASE SURVEYS

Distribution surveys of pole blight in western white pine were limited again in 1956 to examinations of previously uninfected stands. During the course of other field work many of the healthy white pine pole stands on the Colville National Forest in Washington were reexamined for the presence of pole blight. There was no evidence of the disease. On the other hand, the area on the Clearwater National Forest reported as doubtful in 1955 was confirmed as having pole blight this year. It lies outside the previously known range of the disease.

The results of damage appraisal surveys completed in pole-blighted stands were summarized in a paper to be submitted for publication. It shows that past and present damage has caused a serious reduction in the productivity of affected stands. To date nearly one-half of the white pine basal area and one-fifth of the total basal area of these stands is in diseased or recently killed pole blight trees. Mortality varies with age of infection; the old affected stands contain approximately five times as much

mortality as recently affected stands. The annual loss from pole blight amounts to 174 cubic feet per acre over the 102,000 acres presently affected. Other effects of the disease have been a reduction in stocking and size class and a change in dominance and composition of the more important species.

Distribution and damage appraisal surveys of the dwarfmistletoes were started during 1956 on parts of the Colville and Nezperce (Idaho) National Forests. The surveys consisted of observations of dwarfmistletoe occurrence along roadside strips and more detailed study of its effects on sample plots established along lines run perpendicular to the roadside strips. A partial analysis of data from the roadside strip survey shows that 78 percent of the 550 miles covered on the Colville and 70 percent of the 370 miles covered on the Nezperce contained infected trees. In the Colville National Forest, western larch was infected on 86 percent of the miles on which it occurred, Douglas-fir on 76 percent, and lodgepole pine on 25 percent. Comparative values for the roadside strips on the Nezperce National Forest were: western larch 79 percent, Douglas-fir 62 percent, and lodgepole pine 53 percent. The results show that dwarfmistletoe has seriously reduced the productive capacity of many stands and in some cases has caused general stand deterioration. In local areas of heavy infection stand productivity is considerably below normal and there appears little prospect of ever developing fully productive stands as long as infected trees occupy the site.

Dwarfmistletoe was also found in ponderosa pine, grand fir, Engelmann spruce, and alpine fir during the course of the survey of the two forests but appears much less serious in these species except in a few localized areas.

WHITE PINE BLISTER RUST AND MICROCLIMATE

During the year a meteorologist formerly with the U. S. Weather Bureau was added to the disease research staff to study the influence of microclimate on the spread and intensification of white pine blister rust. After completing a project analysis which defines the needs for basic research on this subject, he made an exploratory study of the variation in summer temperatures and humidity at the Priest River Experimental Forest in Idaho. It has yielded information on instrumentation, spacing of stations, personnel required to maintain a station network, and the range in variation of temperature and humidity over a small area.

A wooden radiation shield was designed to hold a maximum and a minimum thermometer. Sixty-two such shelters were constructed and placed on 45 different sites along the ridge to Gisborne Mountain and across the Benton Creek drainage under varying conditions of forest cover, slope, aspect, and elevation. At all 45 sites

shelters were established at 2 feet above the ground to determine the distribution of temperature at the average level of ribes bushes. At 17 of the sites additional shelters were placed at 5 feet above the ground to determine the variation in temperature at the level of ribes bushes from that reported at the standard level for meteorological observations.

An instrument shelter was also designed which would hold a hygrothermograph. Ten such shelters were constructed and placed in the field at the 2-foot level to obtain a continuous record of temperature and humidity. An Assmann psychrometer was used to determine the distribution of temperature and humidity between stations, over predetermined routes or on selected sites on representative days.

The climatological data from this study on the Priest River Experimental Forest have been analyzed. Using relationships established between maximum temperatures on the various sites and those at the main meteorological station, the probabilities of various maximum temperatures being equaled or exceeded at any time and for any period of time were determined for each site. Considering the frequency and duration of occurrence of maximum temperatures necessary to prevent natural spread of the rust, it would appear from this preliminary analysis that on the Priest River Experimental Forest temperatures will inhibit spread and intensification of the rust only on those areas in the open on south-facing slopes below 4,000-foot elevation and then only during certain years.

POLE BLIGHT OF WESTERN WHITE PINE

The Station's research effort in the Northern Region against western white pine pole blight this past year was largely concentrated in the three following activities:

Conclusions from root and soil studies to date.--All data obtained from root and soil studies were analyzed and a number of conclusions drawn. Root deterioration is pronounced both in diseased and in healthy portions of diseased stands and tends to increase with an intensification of pole blight. Rootlet density decreases and rootlet mortality increases as affected basal area increases, showing the close relationship that exists between the health of both the root system and the stand. Greater effective soil depths and available water storage capacities are associated with lower rootlet mortality, higher rootlet density, and less pole blight. This sequence of relationships suggests that edaphic factors influence, to an undetermined degree, the occurrence and severity of pole blight. Rootlet mortality in the upper 3 feet of soil is about two and one-half times greater in diseased stands on hardpan soils and about three times greater in diseased stands

on rocky soils than in healthy stands on good soils. Stands situated on good soils possess three times as many live rootlets as stands growing on hardpan or rocky soils.

Moisture stress studies.--The study established in 1955 to determine the effects of an artificially imposed drought on 90-year-old western white pine trees was expanded during 1956. The soil in two additional areas containing white pine and several other commonly associated species (western redcedar, Douglas-fir, western larch, and lodgepole pine), was covered on June 1 with heavy plastic sheeting laid directly on the ground and fitted about the tree trunks. One plot will be covered continuously to exclude all or nearly all precipitation. The other plot will be uncovered each winter to allow for moisture replenishment and then recovered each spring. Soil moisture to a depth of 6 feet was reduced to a marked degree during the first summer of the test. Observations will be made periodically to determine if the several species included in this test react differently to moisture deficiency.

Four additional soil moisture plots were established during 1956 in the following types of white pine stands: old healthy, young healthy, healthy on rocky soil, and diseased on rocky soil. There are now a total of 16 moisture plots on which moisture sampling is periodically carried out. Soil moisture storage capacities, and rates of moisture depletion and replenishment are being determined in both healthy and diseased white pine stands. This information will help to clarify the soil moisture relationships to the pole blight disease.

An experiment was initiated to determine the effect of moisture stress on root development of seedlings. It tests five species (western white pine, western larch, Douglas-fir, grand fir, and western redcedar) planted and grown on three soil types (rocky, hardpan, and good soil). Two moisture treatments will be used. One will maintain sufficient moisture for optimum growth and the other will attempt to hold soil moisture near the wilting coefficient throughout the growing season. Wildings, approximately 1 foot in height, were planted in a randomized arrangement. Each combination of soil-moisture treatment is replicated twice. Moisture stress will not be imposed until the start of the 1958 growing season in order to allow each plant to establish and grow prior to testing.

Study of the root characteristics and abundance of eight tree species in white pine stands.--A 1-acre area in a pole-blighted stand was selected for a detailed study of root characteristics. Mortality of both rootlets and root tips of white pine was considerably less than of the other species studied except Engelmann spruce, which it exceeds slightly. Mortality in western hemlock

and western larch rootlets and root tips was approximately twice as great as in white pine, and for grand fir, western redcedar, Douglas-fir, and lodgepole pine mortality ranged from two to three times as high as for white pine. However, for roots in the upper 1 foot of soil, grand fir, hemlock, spruce, and cedar had significantly higher root tip quotients (root tips per unit length of root), greater numbers of rootlets per unit length of root, and greater ratios of length of fine root (less than 1.0 mm. in diameter) to length of structural root (1.0 to 5.0 mm. in diameter) than did white pine, larch, lodgepole pine, and Douglas-fir. Of the latter four species, white pine appeared to be the least able to compete for moisture on the basis of root system alone.

PONDEROSA PINE BLIGHT

In the Intermountain Region.--Serious damage by the Elytroderma blight of ponderosa pine occurs on only a small part of the total pine area. The marked localization of the disease strongly suggests that environment is a highly important factor in the epidemic behavior of the fungus. The affected areas are largely confined to the upper altitudinal limits of ponderosa pine where the species intergrades with other conifers such as alpine fir, lodgepole pine, larch, Engelmann spruce, and Douglas-fir.

Most all of the diseased stands are on ridge tops and south and west slopes. Boundaries of infection areas were mapped in 1950. Observations since then show that there has been no extension beyond these boundaries and suggest that aspect is also a factor of ecologic importance associated with the epidemic. Fogs and mists are fairly common in the fall over these areas.

The intensity of the blight epidemic reached a peak in 1950 and 1951. A marked decline in intensity of the disease occurred in 1952 and has continued since then at a slower rate. In 1955 most of the hysterothecia (fruiting bodies of the fungus) and the ascospores produced within them failed to mature, supposedly because of an abrupt weather change involving very high temperatures. A sparse crop of ascospores was produced in 1956. Present evidence, therefore, indicates that the epidemic may now have largely run its course.

Vigor of the host is associated with the fungus attack. Increment of the older pines has been markedly reduced for a number of years and the decline began quite some time prior to the start of the epidemic. Seedlings attacked by the fungus were found to be suppressed individuals of very slow growth rate and with a poorly developed root system. Within diseased areas vigorously

growing seedlings with foliage of a healthy green color are present. This suggests genetic resistance, particularly since many of the large, old trees in the same stands show little or no evidence of the fungus.

The Elytroderma blight may be characterized as a disease largely confined to individual twigs, and usually not all of them. In some cases the extent of infection in a tree is limited to but a few twigs. Blighted twigs eventually die and it is in this manner. that some previously infected trees have now become free of the disease. A pruning experiment was started in 1955 at which time all diseased twigs were removed from 20 young ponderosa pines averaging 2.3 inches d.b.h. In 1956 no evidence of the fungus was found in any of these trees. Information gathered from observations and repeat color photographs plus the results of this experiment suggest that pruning diseased twigs may have a place in timber stand improvement.

For the past 3 years seven different fungicides have been tested each summer season on the pathogen. Results have been so inconclusive that it appears doubtful if any of the materials would be effective in controlling the blight.

Losses on permanent study plots were comparatively light in 1956 and occurred mainly in the smaller size classes. All dead trees showed a markedly reduced growth rate for the past 15 to 25 years or more. Within blighted stands losses from blowdown were much heavier than usual. Combined losses from windthrow, lightning, root rots, and bark beetles far exceeded the losses associated with *Elytroderma deformans*.

In the Northern Region.--*Elytroderma deformans* on ponderosa pine occurs in near epidemic proportions in the San Poil and Curlew Valleys in northeastern Washington. Some mortality has occurred and there is no evidence of a letup in infection. Limited branch infection occurs in ponderosa pine stands on the St. Joe and Kaniksu National Forests in northern Idaho.

STEM RUSTS OF CONIFERS

In the Intermountain Region lodgepole pine is the common host of the blister rust fungus *Cronartium stalactiforme*. No thorough or systematic survey has been made to accurately appraise the prevalence of this disease and the damage caused by it, but during 1956 additional infection areas were discovered in the Region. One stand of lodgepole pine, in which a cursory examination was made last season, had an estimated 90 percent of the trees infected. Damage was heavy.

Pinyon blister rust (*Cronartium occidentale*) was found on *Pinus monophylla* in extreme northern Utah. All previous records of this fungus on pinyon pines in Utah are from the southern part of the state.

The Comandra blister rust (*Cronartium comandrae*) was found more widely distributed in lodgepole pine than previously recorded. Abnormally dry weather conditions were unfavorable generally this season for infection and intensification of the fungus on false toadflax, the alternate host plant. Some ponderosa pine plantations in southern Idaho, established in 1917 and 1918, are being largely destroyed by the pathogen. Tests of various herbicides for the control of toadflax, conducted during the past 2 years, have been unsuccessful to date.

The yellow witches' broom disease, caused by the rust fungus *Melampsorella cerastii*, has caused serious damage in recent years in a number of stands of subalpine fir. The pathogen not only kills trees, particularly in the younger age classes, but also reduces growth increment. Some subalpine fir stands have an estimated 80 to 90 percent of the trees infected.

LODGEPOLE PINE NEEDLE CAST

The lodgepole pine needle cast fungus *Hypodermella concolor* continues its spread and intensification in the Intermountain Region. Although no systematic survey has yet been conducted, the pathogen is now known to be present on eight national forests. There is evidence that it may be considerably more widespread. The oldest infection areas known date back to about 1947.

Trees infected for successive seasons are reduced to needles of the current season, instead of normal retention for 6 to 8 years. Lower branches are sometimes killed. The growth increment of trees attacked for several successive seasons is greatly reduced and in one severely diseased stand that was examined a few trees have died. In this stand salvage cutting of the most severely affected individuals was conducted. Occasional trees show a high degree of resistance to the fungus.

In spring the symptoms induced by winter injury and by the needle disease are similar. This similarity sometimes results in confusion and a wrong diagnosis of the causal agent.

OTHER DISEASES

The eastern white pine root disease at Sylvanite, Montana, reported in 1955 continues to cause limited mortality and has infected additional trees within the plantation. No mortality has occurred in other species. An inoculation study was initiated to determine if the Leptographium organism commonly isolated from infected roots is the cause. Naturally infected root sections were used in inoculations because the organism does not remain viable in culture. A faster growing Leptographium similar in growth rate to those isolated from pole blighted western white pine was also isolated from infected eastern white pine roots and is being used in the inoculation test.

No permanent damage to forest stands was observed as the result of the temperature drop in November 1955. Considerable foliage browning occurred on ponderosa pine in the vicinity of Spokane and along the Coeur d'Alene River valley. Other species suffered to a considerably less degree. No bud killing was recorded and by fall most traces of winter injury were gone. Several western redcedar stands scattered throughout the white pine type suffered abnormal bronzing of foliage and, in some instances, flagging. This was attributed to stand changes, brought about by cutting and to the dry period in late summer and fall.

Considerably less needle cast occurred in larch stands this season in comparison to past years. Several young stands were observed to drop their foliage earlier than normal apparently because of the dry conditions in late summer. No other species appeared to have been affected.

Extensive browning of foliage occurred in aspen stands on the Galatin (Montana) and Kaniksu (Idaho) National Forests. *Marssonia* sp. was associated with most browning on the Gallatin while both this fungus and *Sclerotium bifrons* teamed up to cause the damage on the Kaniksu.

The outbreak of ponderosa pine twig flagging, limited to one drainage on the Nezperce Forest (Idaho) in 1955, did not recur in 1956. Considerable flagging occurred in the overmature stands occupying the south-facing slopes and, while extensive, caused mortality in only a few trees. Isolations made late in 1955 revealed a frequently occurring fungus quite similar to *Diplodia pinea*. Isolations in 1956 from 1955-killed material showed various fungi to be present with *Diplodia* occurring infrequently. No fruiting of *Diplodia* or other fungi was observed. The primary cause, therefore, remains in doubt.

FOREST INSECT RESEARCH

A program of research, insect surveys, and technical assistance on control projects provided full activity for the Station entomologists during 1956. Each of these phases of the program were active at the Missoula Forest Insect Laboratory, the Boise Research Center, and at the Ogden headquarters.

A review of accomplishments for the year shows significant advances. Considerable progress was made in analyzing the overall research program, making plans for termination of some projects and starting new studies. There was a significant increase in interest in the entomological program on the part of cooperators. During the year Station entomologists collaborated with a research committee of the Southern Idaho Forest Pest Action Council in evaluating the present research program in that area and in considering future needs.

Selected examples from each phase of the divisional program in the Intermountain Station area are presented.

RESEARCH

During 1956 two new studies were started. As part of a review of research problems it was decided that expanded studies on spruce budworm and Douglas-fir beetle should not be delayed. Assignments for primary studies of spruce budworm were made at the Missoula Forest Insect Laboratory and for Douglas-fir beetle at the Boise Research Center. The review of other research projects continues and indications are that some studies can be terminated within a year.

Tree Classification Based on Susceptibility to Pine Beetles

A series of seventeen 10-acre plots was established from 1950 to 1952 to test the effectiveness of the ponderosa pine risk rating system in measuring the relative susceptibility of ponderosa pine to attack by the western pine beetle. The system is highly effective in eastside stands of ponderosa pine in California and Oregon. The above plot establishment should reveal its effectiveness in the northern Rocky Mountain region. Biannual plot cruises reveal the accumulative tree mortality by risk classes. Since the plots were established the general level of pine beetles has been quite low. At the present rate of tree mortality from beetle attack it will take a longer period than originally anticipated to obtain sufficient data for sound analysis.

Through 1956 only 23 trees have been killed on the plots by western pine beetle. The following table shows the distribution of mortality within the risk classes. In spite of the small sample it is obvious that combined mortality in risk 3 and 4 trees accounts for the great majority of volume in killed trees.

Table 3.--Number and volume of ponderosa pines by risk classes killed by western pine beetle through 1956 (10 plots)

Risk class	Number trees	Volume	Volume
		Board feet	Percent
1	0	0	0
2	4	3,950	18.7
3	5	3,050	14.4
4	14	14,120	66.9
	23	21,120	100.0

The study has been hampered by tree mortality resulting from a series of winds of hurricane force since 1950. Four windstorms have caused such serious uprooting of trees on study plots that one plot has had to be abandoned. It must be determined at once if other data such as post mortem classification of beetle-killed trees the year of death in the general area can be used to bolster the plot data.

One phase of the study being given special consideration is the possible interference from other bark beetles, notably the mountain pine beetle and the Black Hills beetle, upon tree selection by western pine beetle. Because all three are primary pests of mature ponderosa pine in Montana it will be necessary to determine whether the use of the ponderosa pine risk rating system will be rendered useless where attacks by mountain pine beetle predominate. Preliminary examination of data accumulated during 1956 indicates that the western pine beetle does not range east of the Continental Divide. West of the Divide its attacks are often accompanied by those of mountain pine beetle, the predominance of the latter increasing eastward toward the Divide. East of the Divide mortality was entirely due to attacks of the mountain pine and Black Hills beetles. There is increasing doubt that the designation of the latter two insects as separate species is valid. Morphologically they appear inseparable.

The present study may indicate that for all practical purposes the ponderosa pine risk rating system should only apply east of the Continental Divide unless subsequent studies reflect some tree selection tendencies of the mountain pine or Black Hills beetles.

Selective Logging to Control Pine Beetles

Since 1950 periodic examinations have been made on areas in Montana that were logged according to a selective system under which high risk trees susceptible to attack by western pine beetle were removed. The system was developed in eastside stands of California and Oregon and is being practiced by operators in the northern Rocky Mountains without being tested in the area.

An additional study area was established in 1956 on the Piquett Creek Experimental Forest in Montana. The study is cooperative with Forest Management Research at the Missoula Research Center, the Montana State University School of Forestry, and the Bitterroot National Forest. The united effort will be a sanitation-salvage cutting of the high-risk trees plus a small amount of silviculturally undesirable trees. There will be three treatments, including the check on three different stand density classifications (light, medium, and heavy), replicated once. Accumulated post-treatment mortality data collected periodically will be the criterion for testing the validity of the risk rating system as the basis for selective cutting.

Engelmann Spruce Beetle

Research to obtain biological information that would aid in control efforts was started with the epidemic outbreak of Engelmann spruce beetle in 1952 following severe blowdown.

Work continued until 1956 when final observations were made on this study. Considerable data were accumulated and are now being summarized for possible publication. It has been determined that species may have a 1-, 2-, or 3-year cycle in parts of the northern Rocky Mountains. Value of extreme cold as a control factor was demonstrated following severe low temperatures in 1955 when heavy mortality was observed in 1956.

No additional work was performed in 1956 on the use of trap trees as a control measure. The results of studies from 1953 to 1955 are being summarized. Results varied considerably between areas and apparent good control in some places was offset by indecisive results in others.

During 1956 reports were received that Engelmann spruce beetle was attacking western white pine where it was intermingled with spruce. Attacks were present but brood development was unsuccessful, ceasing before pupation. The concern over the possibility of the Engelmann spruce beetle spreading into white pine appears unwarranted.

Douglas-fir Beetle

Limited studies have been conducted on phases of the Douglas-fir beetle problem during past years in the northern Rocky Mountains. Because of severe losses of timber that are being suffered from this beetle throughout the Douglas-fir type in the Intermountain Station area, a new study was started in 1956.

There is a pressing need for information on the epidemiology of the species. A study of populations and the factors affecting their increase and decrease is essential to the development of satisfactory methods to prevent or minimize losses. Basic to the entire study is the development of satisfactory methods of sampling populations. Work this past season therefore was concentrated on this phase of the over-all study.

Some facts were developed from the initial studies. Intensity of attack in standing trees averaged greater than records indicate for coastal Douglas-fir. A one-half square-foot bark section appeared to be a satisfactory sampling unit. There was a significant difference between the average number of attacks at the bottom, middle, and top of infested trees and samples from the middle of the infested length contained more attacks and showed less variability than others taken toward the upper and lower limits of the infested length.

The marked preference for beetles to attack windthrown trees rather than standing trees introduces the need for reliable methods of sampling populations in downed logs. Attacks are heaviest on shaded portions of this material, especially the north- or east-facing sides and bottom of the stem.

During 1956 the spring brood far outnumbered the summer brood. The fact that there are separate broods during the season makes it essential to develop reliable methods for use throughout the season.

An essential part of the over-all study will be evaluation of natural enemies including disease and other natural factors that exert control over beetle broods. During 1956 it was possible to start an inventory of parasites and predators. Adults that died

during the spring were examined by disease specialists who, although not able to determine the cause of death, did recognize the possibility of disease organisms.

Analysis of data is incomplete. A progress report will be issued covering the results of the first season of work.

Black Hills Beetle

Black Hills beetle is the major insect pest of ponderosa pine in southern Utah. Epidemics have come and gone at almost regular intervals on the Dixie National Forest and Bryce Canyon National Park. The present epidemic started in 1949. By direct control measures infestation has been controlled in many areas, but has developed in new areas. Control action undertaken during the present epidemic, demonstrated that there are serious gaps in our knowledge of the life history, habits, and epidemiology of the Black Hills beetle under conditions prevailing in southern Utah.

In order to clarify some of the biological relationships a limited study was started in 1954. The main efforts so far have been to determine the basic life history of the Black Hills beetle under epidemic conditions in this area. Using standing tree cages it has been possible to determine the periods and characteristics of beetle emergence. Brood sampling has provided fundamental information on population densities, attack patterns, and seasonal development, as well as some data on predators, parasites, associates, and host relationships. Additional work is needed in order to substantiate fully these findings. Efforts will be directed toward expansion of the ecological phase of this study, with particular emphasis on the predator, parasite, host relationship.

Spruce Budworm

A study of spruce budworm was initiated during 1956. While facts on the life history and seasonal history are pretty well known through work in this country and Canada and a satisfactory direct control method is available, there is a need to determine ecological factors bearing on the rise and fall of populations.

Five permanent study plots were established on the Lolo National Forest in Montana. Plans call for analysis of factors operating to reduce populations at various stages of development throughout the season. Collections were made at three stages: (1) when early instar larvae were in tree buds, (2) when larvae were mature, and (3) in the pupal stage. All were dissected to determine extent of parasitism. Incomplete records to date indicate an aggregate parasitism of 50 percent. It is generally considered that an aggregate parasitism of 70 percent or higher forecasts a decreasing infestation.

Bole sections of Douglas-fir were collected last spring to determine relative populations in areas scheduled for aerial spraying. Emerging larvae were saved and representative samples were dissected. While two species of parasites are generally found, the dissection method followed was more suitable to check on the presence of one hymenopterous parasite, a species of *Glypta*. Of a total of 7,580 larvae from all areas, 31.9 percent were parasitized by *Glypta*.

During next season it will be possible to measure the factors throughout a complete life cycle in the established plots.

Budworm studies to date have been insufficient to relate actual populations to subsequent damage. Preliminary observations have been made on this phase in Idaho budworm outbreaks. A work plan devised for a study was prepared and limited field work performed during 1956.

White Fir Needle Miner

The present epidemic of white fir needle miner has been serious in Bryce Canyon National Park and the adjoining Dixie National Forest in southern Utah for about 6 years. Attempts at control with chemicals prior to this period afforded no permanent relief.

In 1955 a cooperative study with the National Park Service was designed and initiated. The objective was two-fold: (1) to determine biological and ecological facts with particular emphasis on the seasonal development of the insect, and (2) to investigate possible methods of control, either direct or indirect, concentrating first on direct methods.

During 1956 it was determined that the needle miner has a 1-year life cycle with the larval stage present from early fall through the winter and until the middle of June. While the date of changes from one stage to another varied considerably, it appears to be tied to accumulative temperatures above 42° F. As more data are accumulated and refinements made in analysis it is hoped temperature relationship can be used in predicting development dates.

An evaluation of damage to the trees in relation to population was initiated. Sampling was done as the larvae reached maturity which coincided with maximum defoliation. Unfortunately, in spite of attempts to select plots at various population levels, developments during the season revealed heavy defoliation at all points. The ratio of needles mined per miner were similar in the

different areas. Needle miner populations did vary some by crown position and size of tree. Seedlings were less heavily infested than poles or mature trees.

Tests of two insecticides, DDT and Malathion, were conducted following procedures used in 1955. Results this year using hand-operated equipment showed that larval mortality in excess of 95 percent can be expected when the needles are sprayed with an oil solution containing Malathion at the rate of 1 pound per gallon. In this spraying, attempts were made to apply the solution at the rate of 1 gallon per acre. The rate was judged by comparison with standard dyed cards developed for use in aerial spraying. The spray appeared equally effective applied any time after the larvae became active in the spring (one-third to one-half grown larvae) until pupation occurred.

It was noted that many trees severely damaged by needle miner were attractive to and succumbed to attacks by the fir engraver, *Scolytus ventralis*.

Spruce Mealybug

Spruce mealybug (*Puto* sp.) is apparently unknown in the United States other than in southern Utah. Here its host is Engelmann spruce of all ages from seedlings to mature trees. The species has been found on about 60,000 acres and its feeding has resulted in considerable killing of limbs, deformity of trees, and limited tree mortality. Lacking observation during the earlier life of the infestation, the rate of deterioration of the infested stand has not been determined.

The infestation is located in extensive stands of Engelmann spruce and the need is present to determine the potential for damage of the pest. To do so, determination of the life history and habits of the species as well as an understanding of possible natural control factors are essential.

Limited studies thus far have determined that at least three seasons are required to complete the life cycle. The species over-winters in two forms, the adult female and immature stages. Hibernation occurs at bases of trees and in duff with migration of young from tops of trees to base and back again the following season. Winged males have been found only occasionally.

Feeding by both adult females and the young takes place on foliage and terminal twigs. Damage to seedlings could seriously interfere with regeneration in the area.

Improvement of Insect Survey Methods

Improvement of both aerial and ground insect surveys is essential. Developments by aerial survey research units at Beltsville, Maryland and the Pacific Northwest Forest and Range Experiment Station will be of assistance to our research program. Efforts are necessary to adapt developments elsewhere to local conditions and to develop new methods that are suitable for special conditions within our areas.

For the first time during the present spruce budworm outbreak in Montana, growth conditions introduced a factor that hindered the aerial surveys. Rapid growth of terminals masked the extent of feeding by larvae so it was impossible to segregate light, medium, and heavy damage. Lower flying patterns were followed coupled with more intensive ground sampling which improved results but did not solve the difficulty. If such conditions occur more commonly, methods must be developed to overcome the handicap.

One of the great needs is improvement in the appraisal of infestations through the application of research developments. In 1955 it appeared that control operations might be warranted against an outbreak of Douglas-fir tussock moth in northeastern Washington and northern Idaho. A research entomologist undertook dissection of pupae and examination of egg masses to see if the trend of the population could be determined. As a result it was decided that parasitism and other natural control factors had reduced the population to a point that little damage would result in 1956. Plans for control were held in abeyance. Developments during the following summer substantiated the prediction and the outbreak decreased to a very low level.

INSECT SURVEYS

The annual insect survey program in the Intermountain Station territory was carried out as planned. The aerial phase of the survey was expanded with approximately 440 hours of observational flying over the forests of Regions 1 and 4. While complete coverage was not attained the most important forested areas were surveyed. It is believed that there are no serious insect outbreaks developing unnoticed.

Ground surveys were intensified. Considerable help was received from cooperators in National Forest Administration, the National Park Service, lumber industries, and from private individuals.

Appraisal surveys were made where situations appeared serious enough to warrant consideration for possible control measures. Reports were furnished to land managing agencies informing them of the status of insect problems on their lands.

A brief summary of the more significant insect situations follows. The spruce budworm was again the outstanding forest pest in Montana and Idaho. There are at present about 3.5 million acres of infestation in the fir stands of Montana and northern Idaho and approximately 650,000 acres in southern Idaho.

The Engelmann spruce beetle epidemic that appeared during 1952 in western Montana and northern Idaho appears to have returned to endemic levels in 1956 with the exception of a few scattered centers. Additional blowdown in the spruce timber type during the past year could result in a population increase unless salvaged. The spruce beetle epidemic in Wyoming on the Bridger National Forest continues at a high level although the past year shows little expansion area-wise.

The mountain pine beetle is relatively quiet in the northern Rocky Mountains but shows disturbing tendencies toward increasing levels in forests in Utah and Wyoming. The outbreak on the Ashley and Wasatch Forests in Utah continues at a high level with an estimated loss for the year of 100,000 trees. The Black Hills beetle has been at epidemic levels in southern Utah since 1949. Control efforts since 1950 have reduced populations in treated areas but new outbreaks develop each year in other sections of the forests. The southwestern pine beetle on the Nevada National Forest recreational areas is being reduced each year by maintenance control throughout the season.

Other outbreaks recorded involve a fir needle miner and a spruce mealybug in southern Utah, four species of defoliators on areas of western larch in western Montana, northern Idaho, and eastern Washington estimated at 100,000 acres, black-headed budworm in Idaho and Montana, and a sawfly on lodgepole pine in Yellowstone National Park.

An unusual outbreak was recorded in Douglas-fir stands in the Craters of the Moon National Monument near Arco, Idaho. There are no previous records in this area of significant defoliation of Douglas-fir by sawflies. Dr. H. H. Ross of the State National History Survey Division at Urbana, Illinois determined the species as *Neodiprion, abietis* complex. Snowfalls forced a postponement of surveys until spring.

TECHNICAL ASSISTANCE

Station entomologists have responsibility for furnishing technical assistance to control projects conducted by land-managing agencies. 1956 was a busy season.

The Station's assistance consists of participation in pre-control planning, advice on methods, materials, and timing of the spray application, assistance in training of operational personnel, inspection during operations, and checking of the results.

Aerial spraying of 1,360,000 acres of spruce budworm infestation in Montana and Idaho was the largest undertaking in 1956. Preparation for the projects, critical timing of aerial phases, and the biological checking required makes aerial spraying one of our most exacting technical assistance activities.

Technical assistance was furnished on Engelmann spruce beetle projects. The outbreak in Montana that has been the subject of control by logging and trap logs since 1952 has decreased greatly. At the present time there are a few isolated spots that still present epidemic tendencies. The Engelmann spruce beetle outbreak that developed on the Bridger National Forest in Wyoming in 1955 continues to pose a serious threat. Logging plus some trap log activity is being used to reduce the infestation. While the outbreak did not expand greatly in area in 1956 it did build up in intensity within the zone of infestation.

A combination of direct chemical control plus logging has been used in southern Utah on the Dixie National Forest and Bryce Canyon National Park for the past 6 years. Drought conditions in the area over the past 7 years no doubt have contributed to weakened tree conditions and the severity of the beetle outbreak. Control in one area produces significant reductions but populations develop to outbreak proportions all too frequently in new areas.

The southwestern pine beetle has been causing severe losses on Charleston Mountain in Nevada for several years. This area is one of high use by the public for recreational purposes. A program of all season survey and chemical treatment has been practiced. Constant attention to treatment of newly infested trees appears to be the most successful method yet tried to reduce losses from this species of insects that has several broods during the season.

On the Teton National Forest in Wyoming a chemical control project was necessary in 1956 to reduce an outbreak of mountain pine beetle in lodgepole pine. The outbreak was confined to an area of about 2,300 acres but groups of infested trees indicated a rapidly increasing population of beetles.

FOREST FIRE RESEARCH

Lightning fires, logging slash, fire-danger rating, fire equipment, fire prevention, and fire behavior were the major fields of activity of the Division of Forest Fire Research during 1956.

Following the pattern of 1955, parts of the West experienced drought, severe winds, outbreaks of lightning fires, and periods of critically high fire danger. In some cases these conditions resulted in mass fire. Unfortunately, in the Intermountain Station territory and elsewhere in the West there was tragic loss of life during some of the fire-fighting operations. These events again point to the need for continued progress in fire control. The key to progress in fire control is scientific research.

COOPERATION IN FOREST FIRE RESEARCH

For several years the Division of Forest Fire Research has reported on the assistance given by cooperating agencies. During 1956 cooperative activities reached a new high, permitting more aggressive attack on several important fire research projects. Much of this activity by cooperators serves as a catalyst to get the work under way. However, the efforts of cooperators do not insure continuation of the projects and maintenance of proper levels of work, nor do they solve all of the problems of research financing and development of needed scientific facilities.

Activities of cooperators in forest fire research during 1956 were as follows:

Munitalp Foundation.--Dr. Vincent J. Schaefer, Director of Research for the Munitalp Foundation, continued as technical leader of Project Skyfire and assisted in studies of fire behavior and general forest fire meteorology problems. Dr. Paul J. MacCready directed the experimental meteorology phase of Project Skyfire and assisted in all field operations in cloud seeding. Donald M. Fuquay was on full-time duty at the Forest Fire Laboratory serving as staff meteorologist and assisting in all phases of Project Skyfire. In addition to these technical personnel, Munitalp provided cash and much scientific equipment for the research program.

Advisory Committee on Weather Control.--During 1956 the Forest Service entered into a formal cooperative agreement with the President's Advisory Committee on Weather Control. The agreement provides for cooperative analysis and evaluation of cloud seeding as a possible means of lightning prevention. To facilitate this activity, the Advisory Committee assigned Robert B. Smith, research meteorologist, and H. J. Wells, chief aerologist, to the Forest Fire Laboratory. In

addition, the Committee provided cash, scientific equipment, and general technical service for the evaluation of the lightning-fire prevention phases of Project Skyfire.

U. S. Weather Bureau.--DeVer Colson, research meteorologist of the Weather Bureau's Washington office, again spent the field season with the Project Skyfire group assisting in lightning storm analysis. W. R. Krumm, fire-weather forecaster at Missoula, gave general assistance on nearly all phases of the fire research program. Fire-weather forecasters at Missoula, Montana and Boise, Idaho and the Weather Bureau offices at Salt Lake City, Utah and at Phoenix and Flagstaff, Arizona assisted in the research program. Special weather forecasts and analyses were prepared by the Severe Local Storm Forecasting Center at Kansas City, Missouri and the Fire-Weather Forecasting Center at Missoula. The Weather Bureau provided scientific equipment, including radar which was built into the Project Skyfire mobile radar unit.

Montana State University.--Robert Steele, of the School of Forestry faculty, worked in cooperation with the Forest Fire Laboratory on the Project Skyfire, logging slash, and fire prevention programs. The staff of the Forest Fire Laboratory cooperated with Steele in the establishment of a new course in forest meteorology at the University.

University of Idaho.--Cooperative logging slash research continued with the Forest, Range, and Wildlife Experiment Station of the University of Idaho. David Olson of the University staff assisted in studies of logging slash volume and flammability and hazard reduction.

University of Washington.--The mobile atmospheric research laboratory built by the University of Washington in cooperation with the Munitalp Foundation, was again an important factor in the gathering of field data for several phases of the fire research program. Dr. Konrad Buettner, of the school of Meteorology and Climatology, assisted in flammability studies.

National Park Service.--All of the national parks in the Station's territory cooperate in the fire-danger-rating program. National Park Service personnel at Dinosaur National Monument and Zion National Park, Utah assisted in fuel moisture studies. Yellowstone National Park operated one of the Project Skyfire cloud and lightning survey stations.

Bureau of Land Management.--In southern Idaho the Bureau of Land Management assisted in fuel moisture and fire-danger-rating research at three stations. Work is continuing on fire-danger-rating research for the Bureau of Land Management areas in Alaska. During 1956 fire-danger-rating data were obtained at 12 Bureau of Land Management stations in the Alaskan interior.

Meteorology Research, Inc.--Under contractual arrangements made by the Advisory Committee on Weather Control, Meteorology Research, Inc. assisted in the Project Skyfire field program in Arizona and in the northern Rockies. This firm provided six research technicians, an airplane, and much scientific equipment.

California State Division of Forestry.--At the end of the year arrangements were made with the California State Division of Forestry for cooperation on Project Skyfire. Shop and laboratory facilities at Davis, California will be used to expedite the program of developing, testing, and calibrating cloud-seeding generators needed in lightning fire research.

National Forest Administration.--During 1956, Regions 1, 3, 4, and 6 of the Forest Service assisted in many phases of the fire research program. National forest personnel operated 21 Project Skyfire cloud and lightning survey stations, gathered and assisted in compiling fire-danger-rating data in seven states, and assisted in logging slash research on three national forests. The fire-weather equipment development project and studies of field operations of fire-danger rating are joint programs between the Forest Fire Laboratory and National Forest Administration.

FOREST FIRE LABORATORY

During 1956 further improvements were made in the scientific facilities at the Forest Fire Laboratory at Missoula. A small laboratory room was partially equipped for electronic research in connection with the Project Skyfire research program. At the end of the year plans were completed for equipping a basement room as a laboratory needed in the development and testing of meteorological equipment and cloud-seeding generators. This laboratory room will include a small wind tunnel, work benches, and equipment for developing, testing, and calibrating instruments.

The main field arm of the forest fire laboratory is at the Priest River Experimental Forest in northern Idaho. The facilities at Priest River are used in fire-danger-rating research, fire-weather equipment development and testing, logging slash flammability experiments, and Project Skyfire.

Development of adequate scientific facilities is one of the major problems facing the Division of Fire Research. Many of the things needed for progress in forest fire control cannot be developed without adequate laboratory facilities and scientific equipment. During 1956 plans were prepared for a forest fire laboratory building proposed for construction at the U. S. Forest Service Aerial Fire Depot at the Missoula airport.

PROJECT SKYFIRE

Project Skyfire continued active field and laboratory research aimed at (1) gaining basic information on lightning fires and storms, and (2) testing the possibilities of preventing or reducing the severity of lightning fires through cloud modification. Project Skyfire involves lightning fire research throughout the western United States. During 1956 the main field experiments were conducted in Arizona and in the northern Rockies.

Cloud and Lightning Survey

The cloud and lightning survey was continued from a network of 22 forest fire lookout stations in Oregon, Washington, Idaho, Montana, and Wyoming. A network of 4 stations was operated in Arizona from mid-May to mid-July. Each day during the fire season the observers at these stations recorded the development, movement, and action of cumulus clouds, middle-level clouds, and upper-level clouds. When lightning occurred they recorded data on location and number of strikes, and prepared a map of the storm path in their area. Reports and maps prepared at each lookout station were forwarded to the Forest Fire Laboratory for compilation of regional summaries. In addition, a radio network was used for daily collection of cloud and lightning data from all Skyfire stations. These procedures enabled the Project Skyfire staff to be kept up to date on the cloud and lightning situation and to make daily evaluations of cloud seeding potentials.

A special training school for Project Skyfire lookout observers was held at the Priest River Experimental Forest. Following the school each Skyfire lookout station was visited to give additional on-the-ground instruction to the observers. This effort resulted in a smooth-functioning cloud and lightning survey network which gathered valuable data for lightning-fire research.

The techniques developed in the cloud and lightning survey should prove useful to fire-control organizations throughout the western United States. Proper information on clouds and lightning is useful in evaluation of fire danger, fire-control planning, dispatching, and in determining fire-suppression strategy and tactics. Furthermore, cloud and lightning surveys are essential in the conduct of cloud-seeding operations. If cloud seeding proves successful as a means of lightning-fire suppression, cloud and lightning surveys may become a standard part of the over-all fire-control operations.

Lightning Analysis

Work was continued on lightning storm analyses in the northern Rockies. Data collected at Skyfire lookout stations, supplemented by atmospheric data collected by the U. S. Weather Bureau, are analyzed

for each lightning storm. During 1956, regional lightning-storm maps were prepared for each storm occurring during the fire season. These studies again show an intense lightning-fire zone extending from the area around the Snake River Canyon on the Oregon-Idaho boundary northeastward to the Bitterroot and Lolo National Forests in Montana and Idaho.

Research on lightning fires is revealing several critical zones throughout the western United States. A summary of lightning-fire occurrence is shown in table 4.

Table 4.--Summary of lightning-fire occurrence in the western United States

	Total lightning fires 1940-1955	Average annual occurrence of lightning fires	Average annual lightning fires per million acres protected	Proportion of total fires that are lightning-caused
	Number	Number	Number	Percent
Arizona	20,029	1,252	64.84	84
Colorado	2,348	147	5.83	35
Idaho	15,997	1,000	34.32	69
Montana	9,720	608	22.43	71
Nevada	464	29	2.09	34
New Mexico	7,736	483	31.52	79
So. Dakota	1,715	107	33.57	62
Utah	1,309	82	3.82	35
Wyoming	1,569	98	7.55	62
California	14,981	936	22.20	26
Oregon	15,503	969	31.46	52
Washington	8,092	506	20.19	28
Western States	99,463	6,217	23.44	48

Cloud Seeding--Arizona

Northern Arizona experiences one of the most critical lightning fire loads in the United States. The Coconino National Forest has averaged 343 lightning fires a year during the 16-year period, 1940-1955. During the mid-May to mid-July period, a dry, isolated type of lightning storm frequently occurs in this area, setting many fires and causing great damage. These local air-mass-type storms can be better understood than more complex storms. Their simpler nature makes them good targets for cloud-seeding research because of a better opportunity to observe and analyze the results.

For all of these reasons the Coconino National Forest was selected as the site of a Project Skyfire field operation during the spring and early summer of 1956. Through the cooperation of the Munitalp Foundation, the President's Advisory Committee on Weather Control, the U. S. Weather Bureau, Meteorology Research Inc., the Rocky Mountain Forest and Range Experiment Station, and Forest Service Region 3, a task force moved to the Coconino National Forest in mid-May to carry on field experiments. Headquarters for the operation were established at the Fort Valley Experimental Forest near Flagstaff, Arizona. The nearby San Francisco Peaks area appeared to be an excellent site to observe cloud growth and action and to test cloud-seeding techniques.

The main objectives of the Arizona operation were: (1) to study local air-mass-type lightning storms, (2) to test cloud-seeding techniques and equipment, and (3) to evaluate possible effects of cloud seeding on lightning-storm development and action. To carry out these objectives the operation involved the use of two aircraft, a mobile radar unit, five ground-based cloud-seeding generators, four cloud and lightning-survey stations at fire lookouts, a radio network, and a wide variety of scientific equipment. The 13-man research group included foresters, meteorologists, aircraft pilots, and field assistants.

A principal result of the Arizona experiment was the development of suitable equipment and techniques for experimental seeding of potential lightning storms over mountainous country. Light aircraft equipped with a high-output silver iodide generator proved very satisfactory for this type of experimental cloud seeding. The aircraft can be deployed underneath the target cloud with the silver iodide crystals being carried into the cloud by convective action. Light aircraft also proved successful in measuring atmospheric factors, taking samples of atmospheric nuclei, and making observations of seeding effects.

The results of 12 cloud-seeding missions show that local air-mass-type clouds can be modified. The most evident modifications include: (1) appearance of virga (precipitation from cloud which does not reach ground), (2) deterioration of cloud base, and (3) glaciation in cloud tops. Cloud deterioration was frequently observed. These factors could lead to a reduction in the severity of lightning and a consequent reduction in lightning-caused forest fires.

Cloud Seeding--Northern Rockies

Immediately following the Arizona experiment, the Project Skyfire research group moved to Missoula to carry on similar experiments in the northern Rockies. A test area was selected in rough, mountainous country on the Lolo National Forest. The test area is a high-lightning-occurrence zone within easy reach of the supporting research

facilities of the Forest Fire Laboratory, the U. S. Forest Service Aerial Fire Depot, the Weather Bureau Fire-Weather Forecasting Center, and the Missoula County Airport. The test area is surrounded, also, by the Project Skyfire cloud and lightning-survey network.

The cloud-seeding experiments in the Lolo National Forest followed the pattern set in Arizona and capitalized on that experience. From late July to mid-September both aircraft and ground-based generators were employed in cloud-seeding tests of growing cumulus clouds. More ground generators were used than in the Arizona tests because of the need to gain more knowledge of this type of cloud seeding for lightning-prevention purposes. Aircraft were used extensively with both aerial and ground seeding to make atmospheric measurements and to observe seeding effects.

The results of the experiment in the northern Rockies again show that growing cumulus clouds can be modified. Appearance of virga, deterioration of cloud base, and glaciation in cloud tops were observed following seeding of growing cumulus clouds. Modification following seeding is not always readily observable. The results of aircraft seeding on growing cumulus clouds are easier to analyze than are the results of seeding from ground generators. The effects of seeding from a network of ground generators may produce more widespread modification, but the results are more difficult to analyze and require detailed observations over a larger area.

The 1956 field program involved pioneer development and testing of special cloud-seeding techniques and equipment. While much progress was made, the field experience showed the need for increased research on cloud-seeding techniques for lightning prevention and on the development of many items of equipment. Analysis techniques likewise require much attention.

As a result of the 1956 experiences, plans are now under way for cloud-seeding research during the 1957 fire season. Extensive tests are planned in the critical lightning-fire belt along the summit of the Bitterroot Range on the Lolo National Forest in Idaho and Montana. These experiments will be aimed at gaining quantitative data on the possible degree of lightning suppression from cloud seeding.

Atmospheric Nuclei Studies

Evaluation of natural cloud action and the effects of cloud seeding requires measurement of the presence of atmospheric nuclei. With an understanding of the presence of atmospheric nuclei it is possible to find out how much additional nuclei are being produced in a given area by cloud-seeding generators. Tracing the plume from the cloud-seeding generators is an essential phase of the over-all Project Skyfire experimental program.

During 1956 techniques and equipment were developed for the measurement of natural-freezing nuclei and nuclei produced by cloud-seeding generators. Aircraft were used to trace silver iodide plumes. A cold box mounted in aircraft is used to study air samples gathered along the flight path. Silver iodide crystals can be seen in the cold box and the concentrations determined. The present stage of knowledge of seeding requirements for lightning suppression indicates that the desired objective is to produce 10,000 silver iodide particles per cubic meter at the bases of convective clouds.

Generator Development and Calibration

The 1956 field program showed the need for a special type of ground-based generator for cloud-seeding operations aimed at lightning suppression. This generator needs to be rugged and easily serviced for field use, economical in operation, safe from a fire standpoint in flammable forests, and it must produce a high output of silver iodide crystals at relatively warm temperatures. During the fall and early winter of 1956 work was started at the Forest Fire Laboratory in the development, calibration, and testing of such a generator.

Generator development and calibration requires special equipment and techniques. The first step in this program was to calibrate existing generators and experiment with methods for increasing their output. A mobile wind tunnel was built for the collection of samples for generator plumes. Techniques were developed for the examination of samples in cold chambers. By the end of the year encouraging progress had been made in the generator-development and calibration program. As a result, it is expected that a high-output cloud-seeding generator will be ready for manufacture in considerable quantity early in 1957.

Radar

During 1956 a completely mobile radar unit was designed, built, and used by Project Skyfire. The radar unit came into being as a result of a cooperative effort by the Munitalp Foundation, the U. S. Weather Bureau, the Advisory Committee on Weather Control, and the Forest Service. Surplus military radar equipment was modified, mounted in a specially built 14-foot trailer, and provided with power from two gasoline engine generators.

The mobile radar unit provides a field nerve center for the Project Skyfire cloud-seeding program. On the main radar scope lightning storms can be detected, tracked, and analyzed. Precipitation echoes seen on the radar scope aid in the evaluation of cloud-seeding results. A time-lapse camera mounted in front of a second radar scope and controlled through an electronic circuit provides a permanent record on film of the life cycle of each storm or cloud sequence.

The Project Skyfire mobile radar unit proved to be a rugged outfit. Preliminary construction was accomplished in the instrument shop of the U. S. Weather Bureau in Washington, D. C. From there the unit was towed to Missoula where construction and testing were completed in the Forest Service shops. Next, the radar unit was moved to Flagstaff for service on the Arizona cloud-seeding experiment. From Arizona the unit was towed to a high peak in the Lolo National Forest in Montana where it aided in the northern Rockies experiment until the end of the 1956 fire season. Through all of this rugged service the radar unit proved relatively trouble-free and satisfactorily performed the job for which it was designed.

The Project Skyfire mobile radar unit is a pioneer effort to employ modern electronic science in attacking the lightning-fire problem. This unit was quickly assembled from available surplus equipment and is by no means in an advanced stage of development. However, even the present rather elementary equipment and the limited experience with it show that radar and other electronic systems can be of great value to lightning-fire research and to fire-control operations. Further development of radar can lead to new and improved methods for detecting, tracking, and analyzing lightning storms, rapid plotting of fire zones, controlling aerial patrols, dispatching fire fighters, and planning fire-suppression operations.

Reporting Project Skyfire Results

At the national meeting of the American Meteorological Society held in New York City January 23-26, 1956 a special session was devoted to Project Skyfire. A panel of five papers was presented as follows:

"Atmospheric Studies from a Moving Weather Observatory", by Dr. Vincent J. Schaefer.

"The Skyfire Cloud Survey", by J. S. Barrows.

"Cloud Measurement Techniques", by Dr. Paul B. MacCready, Jr.

"A Mobile Atmospheric Research Laboratory", by Donald M. Fuquay.

"Thunderstorm Analysis in the Northern Rocky Mountains", by DeVer Colson.

The fire-danger-rating project is made up of three fields of endeavor--developing burning-index ratings and fire-danger-rating systems, training observers and fire fighters, and developing fire-danger-rating equipment.

Developing Fire-Danger-Rating Systems

The Model 8 Burning-Index Meter.--The model 8 meter has now served the Intermountain area for 2 years. This year the meter was used by all fire-protection agencies in Nevada, Utah, Idaho, western Wyoming, Montana, portions of Washington and South Dakota, interior Alaska, and parts of British Columbia and Alberta. The meter is well-received and confidence is held in the ratings rendered by it.

Fuel stick manufacturing program.--A working arrangement with the Forest Service warehouse at Spokane, Washington for fuel stick production has been in effect for several years. The warehouse has production and distribution responsibility; the Forest Fire Laboratory has technical responsibility for the quality of the product. Through experimental work at the warehouse, the quality has been raised so that the sticks are actually made to closer tolerances than specified. At the same time the price of the product has not been increased.

Fuel stick quality control.--Each summer a random sample of fuel-moisture sticks is exposed and measured at Priest River Experimental Forest in northern Idaho. This year's testing, as in the past, showed the product to be uniformly accurate and consistent.

Fuel-moisture stick leaching study.--In the wetter coastal climates fuel-moisture sticks tend to lose up to 2 percent (3 percent under extreme conditions) of their oven-dry weight when exposed all summer under a screen. In the drier inland climates the loss is between 1/2 and 1½ percent. It was thought that a series of hot baths might leach out soluble salts and resin before the sticks were trimmed to their 100-gram basic weight, thus minimizing the difference in loss factors during the field season between wet areas and dry areas.

Eighteen sets of sticks were treated. Three sets were soaked in water at 90° F. for 1 day, three for 2 days, and three for 3 days, and similarly in 150° F. water. Between 1 and 2 percent of the oven-dry weights were lost in this preleaching procedure.

After being exposed all summer at Priest River Experimental Forest the preleached sticks had lost about the same percent of oven-dry weight as had those used in the quality-control test. The general conclusion is that the bulk of the loss during the summer is due to

erosion and not to leaching. At present no means of counteracting this loss is contemplated other than protection under screens.

Type of screening material study.--Three sets of sticks were placed under each of four different types of screens: galvanized iron, aluminum, copper, and an experimental small iron wire screen. The data have not been worked up yet. The raw data indicate that sticks under the aluminum screen may be slightly drier than sticks under the other types. Screens apparently reduce weight loss of fuel-moisture sticks.

Fuel-moisture experiment.--The Bureau of Land Management, National Park Service, and other protection agencies guard many thousands of acres of cheatgrass and sagebrush lands. In order to find the best possible combination of fuel factors to incorporate into the burning-index meter, a study was set up this past summer to observe the reaction to the weather of 1/2-inch fuel-moisture sticks and basswood "Appalachian" slats, both under a screen and in the open. Comparisons were made at two Bureau of Land Management lookouts and at Boise in southern Idaho, two at Dinosaur National Monument, one at Zion National Park in Utah, and one at Priest River Experimental Forest. The data are to be processed in the spring of 1957 and recommendations made to the cooperating agencies.

Alaska study.--The Bureau of Land Management lands in interior Alaska have had no system of fire-danger rating prior to 1956. Seven standard fire-danger stations were installed and measurements were made all during the summer. The resultant burning indexes were compared to actual fire conditions. In general, the reported high rate-of-spread of fires in the fuels of interior Alaska indicates either that the meter rates conditions too low or the rate-of-spread factor exceeds that for any fuels of the Intermountain area. More study is needed to correlate burning indexes with the fire problems of interior Alaska.

Large log study.--Daily measurement was continued of the moisture content of large logs exposed in a clear-cut area and also in a fully timbered area at Priest River Experimental Forest. It is hoped that one more summer's daily measurements will yield significant data for more accurately integrating the reaction of heavy fuels and soils with fluctuations of the weather, both short- and long-term. There have now been three summers of daily measurements, and 10-day measurements have been taken since 1942.

Training

An integral part of forest-fire research is the dissemination of research findings to the technicians of forest protection organizations.

Visits to forests.--A general policy, decided upon in 1955 at a joint meeting of the Forest Fire Laboratory, forest protection agencies, and the U. S. Weather Bureau, is that each forest protection unit will be visited annually either by a Forest Fire Laboratory technician or by a member of the fire-weather forecaster's staff. He, with the forest-fire staffman of the protection unit, inspects intensively at least one fire-danger station and gives all the training that time permits. The fire staffman then attends to bringing the standards of all the fire-danger stations on the protection unit up to the level of the one inspected. This procedure has permitted a very few men to give annual assistance to nearly three dozen national forests and several other public and private forest protective agencies.

Training materials.--Many training aids are now in the hands of fire people. Such aids are the fire-danger station handbook, burning-index prediction methods, projection of burning index in time, aspect and slope, and rate-of-spread tables. Members of the Forest Fire Laboratory endeavor during visits and inspections to acquaint the personnel with these aids, make them easier to understand, and urge their wider use.

Fire behavior training.--The best means for getting fire behavior information to the fire fighter is through a trainer-training program. Fire research personnel cooperate with regional and forest staff men in presenting instruction to key men who in turn carry out training programs on the various protection units. Factors of fire behavior and fire weather that affect blow-up conditions and personal safety are stressed. During 1955 fire-research personnel participated in fire-training programs of the Forest Service in Regions 1 and 4, of the National Park Service, and the Bureau of Indian Affairs. Special emphasis was given to fire training in Utah in cooperation with the Utah State Forester's office.

Fire Equipment Research

The fire-danger-rating equipment designed last year was thoroughly tested this summer at the Priest River Experimental Forest and at other field stations.

Wind counter.--A battery-powered totalizing counter that has a minimum-battery-drain feature has been tested; plans and specifications are ready for final approval before the instrument is put into production. The counter will work with any contact-type anemometer.

Fan psychrometer.--Plans and specifications have been completed for a simple battery-powered, small electric motor-driven-fan unit to replace the hand-crank unit on the Forest Service fan psychrometer assembly. A complete psychrometer assembly can also be built locally if the fan unit and a sling psychrometer are available. The Spokane

warehouse has built 100 units to satisfy immediate demands within Forest Service Regions 1 and 4.

Aluminum rain gage.--Plans and specifications are now ready for a seamless aluminum rain gage that has about the same dimensions as the present galvanized sheet iron gage. Plans and specifications have been completed, also, for a fiber (Lamicoid) rain gage measuring stick to replace the present stick. The fiber gage will not split; it can be washed; and water will not "creep" on it. The U. S. Weather Bureau has adopted the material for its standard measuring stick.

Fuel-moisture screen.--Plans and specifications have been completed for a simplified method of constructing the standard fuel-moisture screen. Screen replacement will be a great deal easier with this new design. A much smaller screen, which includes brackets for the sticks at the proper height, was tested. Sticks under this screen had about the same moisture content as sticks under the standard screen. A simplified design will be field-tested in 1957.

Portable fire-danger station.--All testing of a portable fire-danger station has been completed except for dropping by parachute from a plane. The portable station was used extensively on two prescribed burn areas during 1956. The instrument panel is now being altered to permit easier reading. The portable fire-danger station will be available for general use during the fire season of 1957.

Knock-down aluminum instrument shelter.--The new shelter is a 24-inch cube when assembled, and stands on 48-inch legs. When packed ready for carrying it forms a package only 5 inches thick. The legs fit snugly into a bracing member and can be carried as a single piece. The Missoula office of the U. S. Weather Bureau is now testing the shelter for low-temperature accuracy. Upon completion of these tests and modification of the leg assembly to eliminate vibration during heavy winds, the shelter will be ready for preparation of final plans and specifications.

LOGGING SLASH RESEARCH

Logging Slash Flammability

During 1956 field and analysis work was virtually completed on studies of variations in flammability according to species, age, and amount of logging slash. The only field work still to be completed is experimental burning of plots containing 5-year-old slash. These tests must await 3 more years of slash aging.

Logging slash reaches its highest state of flammability during the first year following cutting. Weather factors, of course, have a strong influence. During the fire season slash of all species becomes highly flammable within a few weeks following timber cutting; thereafter there is a gradual decline in flammability. Slash-treatment measures, therefore, result in the greatest hazard reduction when they can be performed quickly after timber cutting.

Species has an important influence on logging slash flammability. Western hemlock and western larch are examples of species which drop their needles so rapidly that a major reduction in flammability occurs by the second fire season in the life cycle of the slash. Species which retain their needles, especially the pines and western redcedar, show a much smaller reduction in flammability with aging.

Flammability ratings and fire behavior also vary widely by other species characteristics. Species such as the pines, which contain a large amount of needle surface in comparison to stem, branch, and other larger-sized-woody surfaces, exhibit more violent burning characteristics.

Amount of slash is perhaps the most important single factor influencing flammability. Burning experiments at the Priest River Experimental Forest show clearly that heat and rate-of-spread of slash fires increase with the amount of slash present. The effects of amount of slash are especially evident in slash only a few weeks old. However, heavy slash concentrations retain high flammability ratings even after aging for two and three seasons.

The results of the logging slash flammability research will be summarized in a publication now being prepared.

Slash Measurement

Work continued on the development of slash-yield tables which will show the probable quantity of slash per thousand board feet of timber cut according to species, age of stand, site factors, and stand density. During 1956 tree crowns were measured on additional species and age classes. Data from the tree crown measurements in nine major species of the Intermountain West are now being analyzed.

The results of this analysis should indicate the amount of additional field data needed for the development of satisfactory slash-yield tables.

Slash Disposal Methods

Slash chipping was tested in conjunction with dozer piling and hand piling during 1956 on experiments initiated on the St. Joe National Forest. The purpose of these experiments carried out on timber sales is to determine the feasibility of chipping as a means of slash disposal in Intermountain forests. The chipper equipment is mounted on a tractor-bulldozer to provide complete mobility over the timber sale area.

Previous experiments at the Priest River Experimental Forest have shown conclusively that chipping is an effective means for reducing the hazard of logging slash. Preliminary results of the St. Joe National Forest experiments show that chipping may be employed as an important means of slash disposal, but when used alone is not a completely satisfactory method. Chipping shows up best when employed in conjunction with other methods, such as dozer piling, hand piling, and spot burning. Slash concentrations, residual stand, erosion problems, and many other factors vary widely over a timber sale area. Best slash treatments often require a combination of methods.

Application of chipping as a method of slash disposal requires keen analysis of many flammability factors as well as silvicultural and other resource management considerations. Also, determination of when and where to employ chipping requires careful analysis of cost factors. Experiments of the type initiated during 1956 should provide valuable information upon which to base decisions on slash disposal methods.

FOREST ECONOMICS RESEARCH

FOREST SURVEY

Survey Plans and Techniques

A major step forward was made during the year through more intensive coordination of National Forest Administration's timber inventories for management planning purposes and the nationwide forest survey. A forest inventory field manual was prepared that is now being used by timber management units of National Forest Administration in Regions 1, 2, and 4, as well as on the Forest Survey project. Also, a master plan is being prepared for the use of International Business Machines in compiling inventory data for these same Regions.

Aerial Photo Interpretation

Over the past years of increasing expense, it has been a major problem to keep costs of forest inventories at a reasonable level. The most effective means have been the installation of streamlined methods of sampling and greater reliance on the use of aerial photographs for stratifying our samples.

Because of the diversified topography encountered in the Rocky Mountain States, questions have been raised about the acceptability of aerial photographs as a sampling tool. Scale changes occur within and between photographs, forest types and timber volumes may be stratified by elevation, and steep topography and dense stands sometimes hamper accurate photo measurements. The over-all objective of our research in photo interpretation is to find out how serious these questions are, and if they are serious, what must be done to answer them. Research to date has been confined to the practical application of aerial photo interpretation to forest inventories. Basic research in photogrammetry has not been attempted.

A number of studies were completed during 1956 with results of three of them reaching the published stage. They included a series of stereograms combining vertical aerial views with horizontal pairs taken with a stereo camera. With these stereograms the interpreter can study both pairs at one orientation of his stereoscope. This combination helps the interpreter bridge the gap between the backlog of horizontal images acquired through field experience, and the store of vertical images he must have to become a successful photo interpreter. They are very fine training tools.

Because the mountainous terrain causes wide variations in scale, it was found necessary to make adjustments in some of the already developed photo interpretation aids. A new parallax wedge was prepared having three times the span of a standard Forest Service wedge and which equals the parallax range of many floating dot instruments.

Three new aerial photo scale protractors for mountainous areas were prepared. They have base photo scales of 1:10,000, 1:15,000; and 1:20,000, and range from 1:7,000 through 1:24,500. This range of scales covers elevation differences of 2,000 to 3,000 feet above and below the datum plane of the base scale.

Additional interpretation aids being developed include a crown cover scale for conifers and an engineers slope percent scale.

Perhaps the most interesting item is the development of "Composite Aerial Volume Tables for Conifers," now being processed for publication. Preliminary tests of these tables have given photo volume estimates within plus or minus 5 to 10 percent of field measured volumes. These results can mean a great deal to the forest manager especially for obtaining preliminary estimates of volume for timber sales. Studies on the application of these tables will continue.

Other studies completed but not yet published include the effect of topographic displacement on dot sampling and the effect of various minimum areas on dot sampling.

Papers on aerial photo volume tables were prepared and delivered by Karl E. Moessner at the annual meeting of the Pacific Northwest section of the American Society of Photogrammetry at Victoria, B.C., and at the annual meeting of the Northwest Scientific Association in Seattle, Washington. Moessner is also participating in the preparation of the chapter on forestry for the Photo Interpretation Manual to be published by the American Society of Photogrammetry.

Initial Inventory

The field work in Colorado was shifted into high gear at the beginning of the 1956 field season. The Forest Survey Unit through the Rocky Mountain Forest and Range Experiment Station completed final plans for cooperation with Region 2, and ten 2-man crews started measuring field inventory plots. In addition to these men and their leaders, three men were engaged in photo interpretation and delineation of forest cover types and stand size classes within the national forest boundaries.

By the close of the field season, about 3,125,000 acres of forest land had been covered in the field. This is nearly 15 percent of the total area of forest land in Colorado. Of the forest area covered 2,218,000 acres are classed as commercial forest land, or about 26 percent of the total commercial forest land area of the State.

Compilation of data for South Idaho continued and by the end of the year was completed except for derivation of final growth, mortality, and cutting drain statistics. An outline for a combined statistical and analytical report has been prepared and preparation of the report is under way.

Maintenance Survey

With the assistance of Region 1, the tempo of the reinventory of forest lands in western Montana was increased quite markedly. During 1955 about 1,175,000 acres of forest land were covered by the field inventory. During 1956 2,835,000 acres were inventoried. This brings the total area of forest land covered to 6,663,000 acres. The acreage includes about one-fifth of the commercial forest land of the State.

Timber Cut

Annual surveys of pole production in the Northern Rocky Mountain Region and Montana's Christmas tree shipments were made. Release of information on 1954 production of wood-using industries is still waiting correlation with Bureau of the Census data.

This was the ninth year that Montana exported more than 3 million Christmas trees. Even then shipments dropped 7 percent from the record 3.5 million trees shipped in 1954. Three counties, Lincoln, Flathead, and Missoula, shipped over 80 percent of the 1955 crop.

Pole production in the Northern Rocky Mountain area built up slightly after a record low in 1954. Output increased about 6 percent over 1954. Number of poles produced by species and state is given in the following tabulation:

Species	Montana	North Idaho	Northeast Washington	Total	Percent of total
Western redcedar	79,438	42,755	9,667	131,860	44.8
Lodgepole pine	95,027	0	0	95,027	32.3
Western larch	33,925	15,964	11,799	61,688	20.9
Douglas-fir	5,828	97	16	5,941	2.0
Total	214,218	58,816	21,482	294,516	
Percent	72.7	20.0	7.3		100.0

ECONOMIC STUDIES

During 1956 the industrial study of western Wyoming, southeastern Idaho, and northern Utah, was virtually completed. This study was undertaken cooperatively with Region 4 of the Forest Service. A preliminary draft of the analysis was finished in the fall, and in December a conference was held to discuss and review the findings. As a result of this very thorough inspection, several opportunities were revealed for strengthening or refocusing certain statements. The report has been revised for final review and should be ready for publication early in 1957.

In connection with the study mentioned above, the Robert A. Taft Sanitary Engineering Center (Cincinnati, Ohio) of the Public Health Service made a study of the major streams of southern Idaho and western Wyoming. This analysis, made in cooperation with the health departments of Idaho, Wyoming, Utah, and Oregon, indicates that several stretches on the Snake River in Idaho and one on the Green River in Wyoming are suitable for sulphate pulpmills. This is in respect to the capacities of the streams to handle the pollution loads of pulpmills. The findings of the Public Health Service will be published in a research note.

Because of the growing interest in lodgepole pine as a lumber species, a brief research paper has been prepared summarizing the presently available information on the subject. This report summarizes data recently obtained from two outstanding lodgepole pine sawmills in Montana. The manuscript will be published in 1957.

Another major undertaking was the preparation of a report, "The Future Demand for Rocky Mountain Timber." Using the Forest Service Timber Resource Review as a background, this analysis attempts to interpret the long-range timber outlook in the United States in terms of what it may mean in the way of timber industry opportunities for the Mountain States. The general conclusion seems to be that a long-run tightening of the national timber supply picture opens a bright future for growth of industry in this region. Held up awaiting final revision of the Timber Resource Review, this manuscript likewise will be published in 1957.

A large part of the problems of marketing forest products from the Mountain States relates to long distance and high freight costs. For that reason a complete understanding of the marketing by the states in the Intermountain Station territory requires an appraisal of the freight rate and distribution picture. The opportunity to understand better the transportation problem is enhanced by the fact that certain information on railroad shipments is currently being compiled by the Interstate Commerce Commission. This agency annually publishes waybill statistics for all major commodities. A study has

been started to analyze these data to see what light they may shed on the transportation situation. It is difficult to know now how much the study will accomplish, but if the data are as revealing as we hope, they will provide the basis for future marketing studies here and elsewhere.

RELATED PROJECTS

This Division continued to have Timber Resource Review responsibilities. During 1956, S. Blair Hutchison spent several months in Washington, D. C. assisting in the final revision of the report. He has been concerned mainly with long-range growth projections.

In July, Roscoe B. Herrington was transferred from the Forest Survey project to the economic study section. He will be engaged primarily in marketing studies.

FOREST UTILIZATION RESEARCH

Timber products output in the Intermountain Station territory has more than doubled in the past decade. Problems in Forest Utilization Research have grown proportionately. There have been significant utilization changes: new fiber-based industries, improved harvesting practices, better sawmills, and a broader integration of resources. The value of past utilization research has paid off. Yet, we are by no means over the hill in answering many of our utilization problems. Despite the great strides that have been made in recent years, much remains to be done. Some notable accomplishments in the Intermountain Station area during the past year have added to our sum of knowledge.

TIMBER GROWTH AND UTILIZATION RESEARCH

Lumber grade-yield studies have been conducted for more than 40 years in the territory. Although frequently revised, much grade-yield information is now obsolete. Changes in utilization standards, sawmill equipment and practices, and silvicultural methods have necessitated a review of past grade-yield work. Also, it is now becoming increasingly important that stumpage appraisals be made with greater precision than in years past. Not only are timber values *in toto* increasing but the spread between high quality and low quality lumber is becoming more and more pronounced. It is therefore imperative that the differentiation between high quality and low quality logs be better understood and evaluated.

Three cooperative studies were undertaken this past year in lumber grade-yield recovery: one in Douglas-fir, another in ponderosa pine, and a third in western white pine. The Douglas-fir study was designed to develop criteria for log grades for that species including the effects of compression wood on lumber grade yield. The lumber from 121 trees was tallied, dried, surfaced, and graded. Trees, logs, and green-surfaced lumber were all evaluated for compression wood content. Analysis of these data and publication of results will be done by the Forest Products Laboratory.

A study of ponderosa pine was made in central Idaho to determine the validity and usefulness of the Pacific Northwest ponderosa pine log grade rules for this region. Some 500 logs were tallied; analysis of results is under way. A similar study in western Montana was made for western white pine.

Through the efforts of the Intermountain Regional Log Grade Committee a long-range program has been developed to meet our log grade needs. First, existing log grades in pine and Douglas-fir must be perfected to the extent that they are acceptable for general use.

Second, log grades must be developed for other important species such as lodgepole pine, white fir, Engelmann spruce, and others. Third, log grades must be proof tested as they are developed for each species, including tests for local variations in yield. Last, tree grades must be developed, the ultimate need for timber cruisers and appraisal estimators. It may be 10 years before our needs in log and tree grade work are met.

A solution still needs to be found for the harvesting problem of steep mountain watersheds. Reference has been made to these efforts in past annual reports. The studies now being conducted on the St. Joe National Forest in Avery, Idaho with a 3-ton Wyssen Skyline-Crane continue to demonstrate the feasibility of this particular piece of equipment for logging steep ground. Yet, there are still many questions to be answered concerning the economics of the equipment in terms of production quotas for the western logging industry. A second experiment was undertaken this past year on the Payette National Forest in southern Idaho. The R. G. LeTourneau Corporation installed a portable high-lead logging rig in cooperation with the Brown Tie & Timber Company and the Payette National Forest. This machine demonstrated the feasibility of making heavy-selection cuts or group-selection cuts in the ponderosa pine type in steep country with a minimum of soil disturbance. Some obvious limitations of the equipment became apparent during the course of the experiment, but enough was learned to justify continuation of the experiment and the development of a slightly smaller and lighter machine utilizing the same general principles. It is encouraging, indeed, to find that the loggers are as deeply concerned about finding a solution for harvesting these stands as are the foresters. Indications are that added emphasis will be given harvesting studies during the coming few years with more and more operators willingly joining forces with research foresters in solving this aggravating problem.

A growing interest in fiber utilization has prompted industry to begin inventorying its logging residues. Two intensive studies of logging residues were conducted during this past year, one in eastern Washington and the other in southern Idaho. Although it is not yet conceded that the collection and transportation of logging residues is practical, indications are that trees of a lower general standard can be transported along with high-value material where fiber use is an ultimate outlet. We are a long way from being a region of faggot pickers, but there is a progressively improved trend in woods utilization.

The studies of the behavior of twisting poles continue at Newport, Washington and Libby, Montana. The final results of these two studies will be published in the near future. Indications are that green poles with an affinity for twisting can be bad performers after

installation. The direction and the amount of twisting can probably be anticipated and it is still undertain as to whether the pole will ultimately stabilize or not. Still to be studied are the frequency of occurrence of twisting poles, the fundamental causes for the formation of spiral grain, and the possibilities for eliminating or at least minimizing this abnormality. Such studies will involve the physiology, genetics, environmental factors, and microstructure of trees.

PULP AND PAPER

As early as 1915, studies were made of the pulp and paper possibilities for western Montana. A specific study in the Kootenai National Forest at that early time has, after more than 40 years, come to fruition with the announcement by the St. Regis Paper Company of plans for a pulp mill near Libby, Montana. Simultaneously, the Waldorf Paper Products, Inc. have started construction of a kraft pulp mill on the Clarks Fork River near Missoula, Montana. These two announcements offer proof of the validity of recent work done by Forest Utilization Research in which the possibilities for fiber utilization in the northern Rocky Mountain area were emphasized. It is now apparent that the development of a substantial pulp and paper industry in this area has just begun. It is anticipated, from the inquiries received from industry, that additional facilities will be established in the course of time.

Western hemlock is an important species to the paper industry in the Inland Empire. Rot has been a problem of major concern to the paper maker and has necessitated the exclusion of much raw material in the past. A cooperative study of hemlock chip and pulp yield from defective hemlock demonstrates that losses are less significant than was anticipated. It means that a broader use of this valuable species will be possible and pulp capacity in the Inland Empire can be sustained or increased.

With the installation of new pulp facilities, in addition to increases by established pulp mills, it is imperative that the analysis of industry opportunities in the Station's territory be accelerated. This division has worked closely with the Division of Forest Economics in appraising industry possibilities in eastern Montana, and more recently in the headwaters area of the Colorado River. Broadly speaking, it can be said that there are ample wood resources for a substantial pulp industry. Limitations of water, markets, and transportation are localized. Special reports from time to time will point out where possible sites lie.

PHYSICS AND ENGINEERING

The final samples of lodgepole pine, western larch, and western redcedar were selected for the American Society of Testing Materials strength evaluation. Commercial poles of 5 species are being tested cooperatively by the Forest Products Laboratory. Last year the Division reported on the selection of untreated material. This year the selection was of treated poles which will be tested for strength and reported in a special publication of the ASTM. The results of this study, whatever they turn out to be, will be of considerable value to the pole industry of Montana and Idaho, an important segment of our forest industry. Care in the selection of the test material was stressed so that a true reflection of the representative timber going into commercial use was sampled. Since strength is so closely related to specific gravity, selection was made on the basis of a range and an average of gravity.

Some of the smaller sawmills in Utah are manufacturing rough lumber for industrial use. Typical uses are car stakes and blocking used in shipping fabricated steel by railroad. Present Railway Association rules prohibit the use of some of our more common species, principally lodgepole pine. An effort is being made to have the Railroad Rules Committee revise their specifications to include some of these regional species.

The bigger sawmills recognize the importance of well managed and operated dry kilns. Some mills are adding dry kilns to operations that have heretofore had none, and some of the major producers are constructing or remodeling existing kilns to do a better job and to increase their capacity. One such mill just completed a multimillion dollar installation and is now able to reduce its drying time by almost 30 percent. At the same time, the quality of output is apparently improved.

The drying of poles, particularly in northern Montana, is a short-seasoned program when air drying alone is used. One of the major pole producers has experimented successfully with a dry kiln for handling full-length poles. Besides shortening the drying period by a considerable amount, drying in this kiln improves the surface characteristics of the wood, making it better suited for the treating cylinder.

TIMBER PROCESSING

The plywood industry is slowly gaining in its installed capacity and output in this region. There is little likelihood that plywood production will ever rival that of the Pacific Northwest or California, but there are indications that there is ample opportunity for a steady and calculated growth. There was a good market this year for sheathing grades of Douglas-fir plywood and other species, including ponderosa pine, western larch, and cottonwood. There was also a good market for sliced pine veneer which is being produced at one of the plywood factories. Recent announcement of an additional plywood plant at Whitefish, Montana indicates that opportunities for industrial expansion still exist. The successful production of veneer from our native species has depended to a great extent on the research conducted at the Forest Products Laboratory and in the field.

There was continued interest in the production of paper-overlaid lumber by two operators in this region the past year. One produces a thin lumber with a high grade paper covering designed for exterior paneling use. The other produces a lower grade lumber and low-grade paper covering primarily designed for sheathing use. Both of these operations are on the threshold of fullscale commercial production and there is optimism about the ultimate opportunities for producing and selling paper overlaid lumber. Information developed by the Forest Products Laboratory in this new use of wood and paper has been the starting point for all of the pilot plant operations to date.

One company has demonstrated that 1 by 4's can be face laminated successfully by continuous processing into suitable 2 by 4's for studs, rafters, and light joists. Material for pilot plant testing has been produced; commercial production is ultimately contemplated. Present equipment must be modified to put the operation on a full commercial basis, however.

WOOD CHEMISTRY

There is some industrial research being done on the use of wood derivatives. The pulp and paper industry is seeking new outlets for waste liquor. There is renewed interest in the production of commercial galactan from western larch. So far there are no known commercial enterprises based on wood chemistry but indications are that such industries may be forthcoming.

There is one commercial charcoal plant in the region using river bottom hardwoods, salvaged shade trees, and some softwood sawmill residues as raw material. The operation is of the block-kiln type and is managed much the same as block kilns elsewhere. It is felt that there are additional opportunities in this region, particularly in the desert areas of Utah and Nevada, for more charcoal plants.

Certainly the market, particularly on the Pacific Coast, can absorb increased production from this region. There seems to be no letup in the demand for charcoal with a growing trend toward briquetted charcoal.

WOOD PRESERVATION

How much deterioration occurs in logs that are cold decked for as long as 2 or 3 years either with or without water spray is a problem which must be studied in the near future. Considerable volumes of timber are so handled and the aggregate dollar value of inventory decks is high. This problem has been studied only on an extensive basis up until now.

The division has cooperated with the Forest Products Laboratory and the Bolidens Gruvaktiebolag, Skelleftchamn, Sweden in testing of a new process of treating difficult-to-treat woods. The Station is particularly interested in western larch, Inland Douglas-fir, and Engelmann spruce, all three species in which heartwood penetration is difficult. The claims of the Henriksson process are that it can obtain ample penetration and retention in these difficult species. No tests have been conducted as yet but sample material has been shipped to the Forest Products Laboratory and to Sweden for pilot plant experiments.

The Division of Forest Utilization Research will continue to work closely with the other divisions of the Station both in the planning and conduct of experiments. Almost every study in Forest Management and many in Forest Economics have some implication in utilization. Likewise, studies in utilization involve work of these two other divisions. It is imperative, then, that the various divisions work closely together in the development of program plans and experiments. This division will continue to serve as the eyes and ears of the Forest Products Laboratory both in evaluating industry needs and in bringing the results of research as quickly as possible to the forest industries. The Station operates in a big and complex geographic area with a wide assortment of forest enterprises, each requiring a certain amount of specialized assistance. The division will continue to serve them within its capacity.

RANGE MANAGEMENT RESEARCH

Problem analyses are a continuing part of effective long-range research. Where a new research program is being undertaken or a going program is being revised, a formal analysis of land-management and research problems is invaluable. A summary analysis of range problems in the southern (Region 4) part of the Intermountain Station's territory was presented in our annual report for 1952. At present the formulation of range-research problem analyses is going forward actively at the Missoula, Inland Empire, and Boise Research Centers. Highlights of the analysis for the Missoula Center are presented in the following pages, together with selected items of progress from going research projects.

RANGE PROBLEMS AND RESEARCH NEEDS IN MONTANA

In general, Montana ranges appear to be in better condition than those of many other western states. This may be the result of more judicious management than in other areas or perhaps of a shorter grazing season and a more favorable climate. At any rate, there has been a tendency to minimize Montana range problems through comparison with other areas where depletion is much more severe. Although some solace can possibly be derived from such comparisons, it is readily apparent that Montana, too, has many range problems that cannot be ignored merely because they are less advanced than elsewhere.

Problems

During the past century most Montana ranges, like ranges elsewhere in the West, have been damaged by grazing of domestic livestock or big-game animals. In some cases damage has not been serious, consisting of but minor losses in the most desirable forage plants and replacement by less desirable species. In other instances where grazing has been severe, conditions have been greatly altered--undesirable species have invaded, plant cover has been reduced, soil erosion has been accelerated, and forage values have diminished. The chief range management problem, then, is one of restoration, and it is, of course, most acute on areas where soil is being rapidly eroded. Some of the areas that have been damaged most are high altitude herblands, big-game winter ranges, and foothills used primarily for spring and fall livestock range.

The grass-forb ranges occurring at high elevations throughout western Montana vary from rather extensive areas in some mountains to small openings in the forest communities of others. Although these herblands may differ greatly in topography, soil, vegetation, and degree of depletion, they have many things in common. All are subject to extremes in weather--a short growing season with possible killing

frosts at any time, abundant precipitation often coming in high-intensity storms, rapid temperature changes, intense light, and high winds. Steep slopes are common, and once these start to "unravel," soil loss is often rapid. Grazing is mostly by sheep and is concentrated in a short season that corresponds rather closely with the growing period of the plants.

Casual inspections of a number of ranges indicate that practically all have suffered damage in some degree. Although the condition pattern is complex, varying with slope, exposure, soil type, and accessibility, it is readily apparent that plant cover of extensive areas has been greatly reduced and that accelerated erosion is taking place. In some areas practically all vegetation has been destroyed and erosion is progressing at a very rapid rate. As a matter of fact, all soil has been lost in a few places, exposing bedrock. Examples of these high-elevation problem ranges are on the Big Timber, Gardiner, and Hebgen districts of the Gallatin National Forest, the Sheridan district of the Beaverhead, and the Lincoln district of the Helena. Undoubtedly there are many others on practically every national forest or mountain mass in Montana. These high ranges are particularly important from the watershed standpoint, probably yielding more water per acre than any other type. Since runoff and erosion originating here can cause serious flood and siltation damage, it is particularly necessary that vegetation and soil of these herblands be stabilized.

Most south-facing slopes in western Montana may be regarded as big-game winter range. Although having wide vegetal and elevational variation, these winter ranges have one thing in common--a relatively light snow cover. Condition is generally unsatisfactory. On extensive areas, desirable browse species such as mountain mahogany and bitterbrush are severely hedged and the plants are low in vigor. On some ranges most of the shrubs are already dead. Perennial grass and forb cover has also been greatly reduced, exposing much bare ground and allowing invasion of annuals. Accelerated erosion is widespread, and on many spots much of the normally shallow soil mantle has been lost.

The ranges of the foothills and valleys normally receive their greatest use from livestock in spring and fall. Some are subjected to additional grazing pressure by antelope at all seasons, by elk and deer in winter, or by livestock during summer. Vegetation of these ranges has also been greatly influenced by such animal life as grasshoppers, crickets, squirrels, gophers, mice, and rabbits. Furthermore, cultivation and subsequent abandonment has often been responsible for extreme changes. As a result, the original vegetation has been largely destroyed, and it is difficult to find even small areas that appear to be representative of pristine conditions. Although considerable bare ground has been exposed, soil erosion generally has not been severe, probably because of the rather gentle topography.

Ranges used primarily by cattle in summer are often in better condition than others, but it must not be assumed that they are entirely free of problems. Many of these are presently in no better than fair condition, and on many a downward trend is evident. Most of these ranges, however, should respond readily to improved management. On a few areas, deterioration has reached an advanced stage. Examples of such depleted conditions can be found on the Rock Creek district of the Custer National Forest, the Hebgen district of the Gallatin, the Whitehall district of the Deerlodge, and the Sheridan district of the Beaverhead.

On many of these ranges, problems have been intensified by loose, granitic soils which are naturally droughty and erosible. With loss of fine materials, water-holding capacity and fertility have been lowered, and conditions have become less and less suitable for growth of vegetation. Such soils have developed on granites from the Idaho and Boulder batholiths as well as on Archean gneisses and associated granitic intrusions, and occur mainly on and adjacent to portions of the Bitterroot, Beaverhead, Deerlodge, Helena, and Gallatin National Forests.

An important problem involving grazing and forest regeneration arises mainly from the common tendency for dominance by either the animals or the trees and requires the establishment of a balance between the two land uses. On some areas, grazing is controlling the vegetation by preventing establishment of coniferous reproduction, whereas on others forest regeneration is controlling grazing use by crowding out forage plants. Although depleted vegetation and accelerated erosion may intensify problems on some areas, for the most part plant cover is adequate for soil protection. In this respect, timber-grazing problems differ greatly from those previously considered. Damage to tree reproduction by grazing animals is serious, particularly on certain big-game winter ranges. Conditions are especially critical in Lincoln County where maintenance of the most valuable timber species, ponderosa pine, is being threatened by grazing of white-tailed deer. Elsewhere reproduction of both lodgepole pine and Douglas-fir is being subjected to various grazing pressures by both livestock and big game with only limited knowledge of effects of such use. Livestock, of course, are much easier to control than big game, but at present there is little basis for total exclusion or application of various systems of management. On the other side of the problem is the reduction of acreages being opened by fire at the same time that big-game populations are increasing markedly. Although new areas being opened by logging are partially compensating, silvicultural treatments aimed at immediate regeneration tend to reduce forage values.

As indicated in the 1955 annual report, spread of noxious weeds on both range and forest lands is another major problem. As would be expected, invasion by these weeds has been most rapid on areas where the native vegetation has been severely disturbed, as on overgrazed ranges and cut-over timber lands. Some of the most abundant are goatweed, Canada thistle, knapweed, wyethia, tarweed, and leafy spurge.

Research Needs

It should be noted at the outset that action based on present knowledge can improve a number of unsatisfactory range conditions, and therefore research needs are not necessarily greatest on problems listed as being most critical. Although all the studies included herein are considered essential to proper management of the resource, an attempt has been made to discuss them in order of decreasing importance.

The most urgent need appears to be ecological studies of the various range types in order to provide a basis for improved management. It is especially important to know the potential of particular sites, patterns of succession and destructive change, and effects of the various environmental factors. In the past, management has often been ineffective because lack of such information has prevented proper classification of range condition, recognition of trend and its rate of progression, and determination of reasons for observed changes. Not only is it important to know the effects of grazing by domestic livestock, but also, effects of other factors in the range complex such as big game, weather, fire, rodents, insects, and soil-dwelling microfauna.

Also of high priority are studies of timber-grazing relations to determine how satisfactory reproduction can be achieved under use by livestock and big game. As already mentioned, establishment of ponderosa pine seedlings on winter deer range is of special importance. Effects of grazing on regeneration of lodgepole pine and Douglas-fir are also in need of study. On the other hand, investigations should be made to determine what silvicultural treatments create the most desirable habitats for game. Certain cutting practices or slash disposal methods might well serve to encourage forage plants, particularly browse. Increasing forage production by seeding herbaceous and shrubby species may also have a place in some areas.

Livestock-game relations should be studied to determine relative effects on the various types of vegetation, how to recognize utilization by different animals, and to what degree they compete for forage. So far, this field of research has been given but little attention. Until such information is available, there can be no sound basis for management of ranges grazed by both livestock and big game.

Artificial revegetation research is needed in two special fields: high altitude herblands and winter game ranges. Studies of adapted grasses and methods of planting have provided guides for successful seeding of many ranges, but the high elevations have been largely neglected. In view of the depleted condition of many high ranges, it appears that artificial revegetation may be the only means of restoration that can be accomplished within a reasonable period. Winter range for big game is particularly short, and the situation is becoming more and more critical as a result of continuing depletion of these areas. At least part of the solution to this problem must come from research on habitat improvement, particularly browse revegetation.

Ecological life history studies of the various noxious weeds should be made. Although methods have been developed for eradicating many of the weeds, control is only temporary unless provisions are made to prevent reinvasion. Furthermore, certain direct control methods that are satisfactory on cultivated lands are too expensive for use on the range. For these reasons ecological studies are necessary to determine what conditions are necessary to prevent reinvasion following eradication or how indirect control through management can be achieved.

Research on grazing summer livestock ranges has been inadequate not only in Montana but in the entire Intermountain area. Results from studies in this region on management of spring-fall and winter ranges are partially applicable, as well as those from summer range studies in other regions; however, local intensity, season, and system studies are needed to provide satisfactory guides for management of Montana summer ranges. Although management studies are needed on ranges at several different altitudes, first consideration should probably be given to those at intermediate elevations where condition is generally fair or better, but trend is often downward. Since these are mostly cattle ranges, this class of stock should be used in grazing management studies. If studies can also be made on high-altitude herblands, sheep should be used. In connection with management studies, it would be well to investigate the utility of artificial disturbances to vegetation and soil as a means of separating effects of forage utilization and trampling which are confounded in actual grazing trials.

A universal need that should not be overlooked is methodology for measuring vegetation and changes therein. Although many advances have been made in this field, no methods have yet been developed that are wholly successful. Opportunities to explore methodology, therefore, should not be ignored, particularly when tests can be integrated with other range research projects.

Tentative Plans

At present only one man is assigned to the range research project in Montana. In view of the current emphasis on allotment analysis and the need for criteria of condition and trend, his major effort will be directed at ecological studies of the important range types. In addition to studies of site potential, patterns of change, and effects of environmental factors, it may also be possible to include some life history studies of individual species, particularly noxious weeds. Most of these studies should be planned on a long-term basis, but some "quickie" studies will undoubtedly suffice to provide immediate answers.

If a second man can be added to the project, he will work primarily in the field of grazing in relation to forest regeneration. The problem of obtaining satisfactory tree reproduction on areas grazed by big game should receive highest priority, but effects of livestock grazing should also be studied. Such studies will include consideration of methods for increasing forage production on cut-over areas.

It would be desirable to have a third man assigned to the project to work on game-livestock relations on nontimbered ranges, particularly east of the Continental Divide. He could also carry on browse revegetation studies for rehabilitation of winter game ranges.

Before initiating studies in the field of game range management, possibilities of cooperation with other agencies and organizations will be fully explored. Also, careful consideration will be given to division of research activities between men.

It would be desirable to resume livestock management studies at the Vigilante Experimental Range, but this should not be done unless adequate financing can be assured. In the past the program has been largely one of expediency because of insufficient funds, and consequently was somewhat ineffective in providing guides for management of summer ranges. An effective program at this experimental range would require at least one permanent man with temporary field assistant help. In view of the need for information on management of mountain ranges, it is unfortunate that full advantage cannot be taken of the facilities available at Vigilante.

Effects of Heavy Grazing by Deer and Sheep

Excessive stocking by deer and sheep has produced characteristic ecological changes in foothill ranges of Utah. Table 5 illustrates such changes in the juniper-sagebrush-bitterbrush type grazed by deer in winter and by sheep in spring and fall.

Table 5.--Plant growth and range condition in relation to grazing use on juniper-sagebrush-bitterbrush type

Forage	Good condition range	Range heavily overgrazed by		
		Sheep only	Sheep and deer	Sheep + severe deer use
	Plant growth-lbs. per acre air-dry			
Bitterbrush	730	440	300	15
Sagebrush	470	935	160	3
Other shrubs, mainly rabbitbrush	90			
Perennial forbs	330	Trace	25	Trace
Perennial grasses	330	10	20	2
Total	1,950	1,385	505	20
Bare soil-percentage	7.4	37.6	46.5	57.3

Good condition range had an effective ground cover of mixed grasses, forbs, and browse well suited to both deer and livestock grazing.

On overgrazed sheep range, practically all perennial forbs had been eliminated and perennial grasses occurred only under protection of shrubs. Bitterbrush, which is palatable to sheep as well as deer, showed signs of hedging but was still fairly vigorous. However, no young plants under 14 years old were present, indicating unsatisfactory condition for this important shrub. Sagebrush was vigorous and reproducing, but despite its apparent increase, 37.6 percent of the soil was bare and much topsoil had been lost. Annuals, particularly cheatgrass, are often abundant on such areas in years of plentiful rainfall.

On range overgrazed by both deer and sheep, shrubs as well as herbs had decreased, with a further increase in bare ground. Bitterbrush, although it still produced considerable forage, was severely hedged and no young plants below 15 years of age were present.

Heavy sheep use accompanied by severe winter deer browsing resulted in destruction of both bitterbrush and sagebrush. Under such severe overstocking all available green shoots of both species are utilized. But because sagebrush is less able to "hedge up" and protect itself, and because it does not sprout from the base or from older stems as does the more palatable bitterbrush, it succumbs sooner to severe overuse by deer. With this destruction of browse, additional bare soil is exposed to erosion.

Range Condition Affects Deer-Herd Productivity

Cooperative studies with the U. S. Fish and Wildlife Service and Utah State Fish and Game Department show that condition of summer range has a decided influence on deer-herd productivity. Table 6 compares forage and deer-herd productivity on a severely overstocked and depleted summer range in central Utah with one moderately stocked and in good condition for deer in southern Idaho. The winter range of both herds is in poor condition.

Table 6.--Deer-herd productivity in relation to production of good and fair deer forage on two summer ranges in contrasting degrees of condition

	Depleted range	Good-condition range
Forage present, pounds per acre, air-dry		
Good deer forage	104	598
Fair deer forage	160	227
Total good and fair forage	264	825
Deer-herd productivity		
Ovulation rate per doe	1.31	1.95
Fetus rate per doe	1.18	1.85
Average weight in pounds of fawns in October	38.5	60.5

All good and fair forage species on the depleted area were heavily utilized by September, while on the better range good forage was plentiful season long.

Good forage species on the moderately stocked range included a variety of both herbs and shrubs. Several of these same choice plants occurred only as remnants on the depleted range, indicating that at one time this range also supported a cover of good deer forage.

Deer-herd productivity, as indicated by both ovulation and fetus rates, was about 65 percent greater from summer range in good condition than from depleted range. Likewise, weight of fawns in October was nearly 65 percent greater. It is reasonable to expect that there would be an even greater difference in net increase in the two herds, since the fawn drop and survival are known to be greater for deer in good condition than for deer suffering from malnutrition.

Although most deer range problems occur on winter range, it is clear that condition of summer range is also of material importance. This is true not only from the standpoint of forage production and watershed protection, but also from the standpoint of efficient deer-herd productivity.

SUMMER RANGE

Forage Utilization in the Aspen Type

It is often observed where openings occur adjacent to large stands of aspen that the herbaceous vegetation of the openings is sparser, shorter, and made up of less desirable forage species than the more luxuriant vegetation under aspen. On some depleted ranges, for example, the openings may be dominated by annual weeds with very few perennial species, while the adjacent understory vegetation may be a fair stand of perennials of moderate or low palatability.

One of the factors that might be responsible for this difference in ground-cover vegetation is a parallel difference in grazing pressure--if one exists. One sometimes hears it said that utilization by grazing animals is closer in openings than under aspen. Attempts to trace down the origin of these statements in the form of factual observations, however, have led nowhere.

To investigate this question as part of a study of several years' standing on the productivity potential of the aspen type, some formal observations of utilization were made in 1955 on the Manti-LaSal National Forest in central Utah. For most of these observations, parallel transects of meter square plots--usually 5 or 10 in a given location--were run in openings and under nearby aspens, and on these plots percentage-utilization estimates were made of total production by species.

Although the observations are classified with respect to sheep and cattle grazing, some utilization was by mule deer. In most instances, deer utilization could not be segregated from utilization by livestock. It is believed that the amount of forage consumed by livestock on these study areas was much greater than the amount consumed by deer.

The Olsen Creek area dealt with in table 7 had been grazed by sheep one or two weeks before the July 16 observations. In general there is not much difference between the utilization measurements under aspen and in the opening, although there is a slight tendency for utilization figures in the opening to be the higher. Only in the cases of Vicia and Viola do the differences appear to be significant.

Table 7.--Utilization by sheep under aspen and in adjacent opening in early summer and late fall, 1955, Olsen Creek

Forage species	July 16		October 19	
	Under aspen	Open	Under aspen	Open
	Percent	Percent	Percent	Percent
Agropyron trachycaulum	4	4	7	[1]7
Bromus carinatus	9	10	13	[1]16
Poa pratensis	12	20	9	66
Achillea lanulosa	6	13	-	-
Aster chilensis	35	39	13	46
Penstemon rydbergii	20	22	-	-
Taraxacum officinale	33	42	19	[1]21
Vicia americana	7	26	-	-
Viguiera multiflora	25	31	9	24
Viola nuttallii	4	20	-	-

[1] Utilization of fall regrowth. Most of summer growth utilized.

At first glance, the figures for October 19 appear to be little more impressive, only those for Aster and Viguiera being greatly different. In fact, however, utilization in the opening was much the heavier. The figures recorded are only for utilization on regrowth for Agropyron, Bromus, and Taraxacum when actually most of the season's growth had been grazed. The amount utilized was at least two-thirds or three-fourths of that produced, and the vegetation was too far gone to permit satisfactory estimates. The figures for utilization under aspen, in contrast, reflect utilization based on total growth. It may be wondered why some utilization figures under aspen are shown to be greater in July than in October. The reason is probably that the total amount of growth was greater in October.

Similar observations on cattle range in Twelvemile Canyon, with estimates based upon total production, show markedly heavier use in openings than under aspen (table 8). Higher up in Twelvemile Canyon, on areas that had not been grazed by cattle at the earlier date of observation, there were also marked differences by October 20 (table 9).

Table 8.--Utilization by cattle under aspen and in adjacent opening in early summer and late fall, 1955, Twelvemile Canyon

Forage species	July 15		October 20	
	Under aspen	Open	Under aspen	Open
	Percent	Percent	Percent	Percent
Agropyron trachycaulum	4	30	12	87
Bromus carinatus	3	17	18	88
Taraxacum officinale	5	26	-	-
Vicia americana	2	8	-	-

Table 9.--Utilization by cattle under aspen and in adjacent openings, October 20, 1955, at two areas north of Mt. Baldy Ranger Station

Forage species	Area 1		Area 2	
	Under aspen	Open	Under aspen	Open
	Percent	Percent	Percent	Percent
Agropyron trachycaulum	38	90	6	56
Bromus carinatus	54	86	16	55

Several comparisons in Ephraim Canyon reveal the same essential pattern on common-use range. In each case utilization is heavier in openings than under aspen.

The foregoing figures, which vary greatly from place to place but maintain a remarkably consistent pattern whether sheep or cattle, or both, are the principal grazing animals, show definitely that grazing pressure is greater in openings than under an aspen canopy. Why this should be so is not known. It seems probable, from the work

of Welton and Morris on woodland pasture in Ohio (Jour. Forestry 26: 794-796, 1928) that unshaded plants in the open are able to manufacture more sugars than those in the shade of aspens, and so are relished more by the animals.

Plant Production on Seeded and Unseeded Subalpine Range

In 1951 the Manti-LaSal National Forest seeded an area of 435 acres in the head of Manti Canyon at an elevation of about 10,000 feet. This was depleted cattle range, dominated by forbs that were for the most part unpalatable to cattle. They included *Geranium richardsoni*, *Artemisia discolor*, and *Viola nuttallii* as dominants; grasses were very scarce. From 50 to 75 percent of the soil surface was exposed over extensive areas, where no more than 25 to 30 percent should be exposed on this important watershed if it were in good condition.

Portions of the area were left unseeded in order to provide comparisons of seeded and unseeded range. The information in table 10 summarizes results from comparisons of 60 paired 9.6 sq. ft. plots on the seeded range and comparable unseeded range in 1956. Cover was determined by use of the point analyzer, and production by the weight-estimate method.

Table 10.--Cover and green-weight production on unseeded and artificially seeded subalpine range at the head of Manti Canyon four years after planting

Type of cover	Cover		Production per acre	
	Seeded	Unseeded	Seeded	Unseeded
	Percent	Percent	Pounds	Pounds
Grasses	19	5	1,514	220
Forbs	11	26	783	1,748
Litter	10	10	-	-
Total	40	41	2,297	1,968

Total cover under the two conditions is about the same; but on the seeded range, grasses make up about half the total, and on the unseeded range, forbs make up nearly two-thirds of the total. This is what one would expect, since plowing destroyed many of the forbs, and most of the species planted were grasses. It is notable that litter on the seeded areas has built up in 4 years to make as much cover as that on the unseeded areas. This reflects both the rapid decay of litter from forbs and the relative persistence of the more highly lignified grass litter.

The production figures show that total production (green weight) is 329 pounds per acre greater on the seeded than on the unseeded areas. Grasses produced 1,294 pounds per acre more on the seeded, and forbs 965 pounds per acre more on the unseeded range. Actually, the unseeded areas had improved during the period since seeding because of relief from grazing, and grasses are more abundant there now than they were 4 years ago. During the past 2 years, when some grazing has been permitted, the cattle have tended to concentrate on the seeded areas so that the unseeded range has been grazed less heavily than formerly.

This high-mountain planting demonstrates that, through seeding palatable grasses, cattle can be encouraged to forsake formerly overgrazed portions of the range to allow their natural recovery. A problem may arise in getting the desired utilization on nonseeded areas, but perhaps as their condition improves they will become more attractive to cattle.

SPRING-FALL RANGE

Seed Source of Sagebrush Reproduction on Burns

For a number of years studies have been conducted at the Upper Snake River Experimental Range to determine the immediate source of seed that gives rise to sagebrush seedlings on burned-over areas. These studies indicate that sagebrush seedlings arise both from seed introduced onto burns from adjacent unburned seed sources and from seed stored in the soil. Wind-borne seed appears to be restricted to areas fairly near the unburned seed source; residual seed appears to be by far the greater source of seedlings on the major portion of large burned-over areas.

Root Nematodes in Crested Wheatgrass

Decline in crested wheatgrass stands after a few years of high production has been noted by many workers. Among the explanations offered for this decline are exhaustion of soil nitrogen and "decadence" of the plants. Recent research suggests that a buildup of parasitic root nematodes may be a cause.

Interest in this subject goes back several years. In 1955 Mr. Gerald Thorne (then of the U. S. Nematology Field Laboratory, Salt Lake City; now a member of the faculty of the University of Wisconsin) collected soil samples at the Benmore Experimental Range and in Ephraim Canyon, mainly in experimental plantings. From these few samples he distinguished 19 species of nematodes at Benmore and 21 in Ephraim Canyon. In each of these samples there were hundreds of individual nematodes per pound of soil. Some were known to be ectoparasitic feeders on plant roots, many were saprophagous, feeding on

decaying organic matter, some were predators feeding on different soil organisms, including other nematodes, while the food habits of several were unknown. Mr. Thorne concluded that Tylenchorhynchus cylindricus, which was found in all six samples at Benmore, was probably the most important species at that experimental range. These nematodes were washed from soil samples: it remained to be shown that nematodes did in fact parasitize crested wheatgrass roots.

With the help of Mr. Thorne and his successor in the Nematology Field Laboratory, Mr. Edsel Jorgensen, a cooperative-aid project was set up by the Intermountain Station with the University of Utah. A student, Mr. David Havertz, was engaged to explore the subject further.

Mr. Havertz was successful in demonstrating the presence, in stained microscopic slides, of several individuals of Nothotylenchys (acris?), an endoparasite, in the roots of crested wheatgrass. The fact that nematodes do indeed parasitize crested wheatgrass was thus established.

In a subsequent study Mr. Havertz fumigated soil known to be infested with nematodes, using ethylene dibromide. A series of 10 clay pots was planted with this fumigated soil, and a parallel series of 10 pots with comparable unfumigated soil. Crested wheatgrass seeds were planted in each pot; and 21 days after planting, the seedlings were thinned to make the paired pots as comparable as possible. The plants were watered each day in the greenhouse. The measurements recorded in table 11 were taken on pairs of pots at four successive dates. Since the soil had to be washed to ascertain nematode numbers, a different pair of pots had to be used at each date.

Table 11.--Height growth of crested wheatgrass plants, and numbers of parasitic nematodes per pound of soil in fumigated and unfumigated greenhouse pots

Date	Maximum height		Average height		No. of nematodes	
	Fumigated	Unfumigated	Fumigated	Unfumigated	Fumigated	Unfumigated
	Cm.	Cm.	Cm.	Cm.	Cm.	Cm.
Oct. 3	37.4	21.1	24.4	15.6	0	125
Oct. 19	28.3	24.0	23.9	18.7	0	116
Nov. 7	28.1	28.7	24.1	21.6	0	1/ 14
Nov. 30	32.0	25.6	22.7	15.6	0	138

1/ All female

There is a very marked difference between the paired pots, the plants growing in fumigated soil being much more robust and leafy than those in unfumigated soil. The measurements in table 11 reflect this difference in some degree and suggest, indirectly, that nematodes do have a depressing effect on the growth of crested wheatgrass seedlings. There does not appear to be a progressive effect within the 2-month interval at this stage of crested wheatgrass growth, but the consistent depression (with the exception of one maximum-height measurement) does suggest a real effect. These preliminary results support the hypothesis that nematodes can build up to such proportions as to retard growth of mature plants of crested wheatgrass, and thus make a material reduction in yield.

The commonly observed dying out of portions of crested wheatgrass tufts and, indeed, of entire plants, which many have regarded as "natural," may in fact, then, reflect parasitism.

WATERSHED MANAGEMENT RESEARCH

Many kinds of watersheds are to be found in the 300-million acre territory within which the Intermountain Station has research responsibilities. A number of conditions affect the manner in which these watersheds dispose of rainfall and snowmelt water as streamflow. Some are of natural origin, such as differences in topographic, geologic, and climatic characteristics. Another is natural variation in vegetation, ranging from widely spaced desert shrubs to densely timbered forests. Other conditions are due to man's activities on the watersheds. Many have been burned--some repeatedly. Others have been crisscrossed with roads. Still others have been dredged and redredged for minerals. Water has been impounded in some and diverted from others. Some valley basins have been drained of stored water by pumping while others have been supplemented by irrigation. Finally, many watersheds have been grazed--some excessively--and others have been logged for timber. All of these activities have changed in some degree the amount, quality, and timing of streamflow yielded by these lands. Some have had a beneficial effect and improved the usability of water. Others have caused detrimental effects.

The effects of land use on the runoff and soil stability characteristics of these forest and range watersheds have given rise to three kinds of watershed management problems:

1. How to restore runoff control and soil stability on watersheds that have been damaged by use.

2. How to maintain such control and stability on undamaged watersheds under continued resource use.

3. How to increase the amounts or improve the timing and quality of water yields.

Satisfactory solutions to these problems require knowledge and understanding of how watersheds receive, store, and yield water; how those hydrologic processes are affected by both natural and man-caused influences, and of the land management practices needed to make best use of them for each intent of watershed management. Development of such knowledge and understanding is the job of the Watershed Management Research Division. During the past year progress was made toward a solution for each of these three problems at various locations in the Station territory.

WATERSHED MANAGEMENT PROBLEMS AND RESEARCH

A comprehensive analysis of the watershed management problems and research needs in the Northern Region was completed in the past year. This portion of the Station territory embraces the headwaters of two great river basins: the Columbia in western Montana, northern Idaho, and northeastern Washington, and the Missouri in central and eastern Montana and northwestern South Dakota. Following are some of the highlights of that analysis:

Water Situation in the Columbia and Missouri Basins

The Columbia River discharges an average annual runoff of close to 180 million acre feet. Of this amount approximately 41 million acre feet are produced on 35 million acres in the Northern Region. Of about 59 million acre feet average annual runoff from the Missouri River, approximately 17 million acre feet come from 82 million acres within the Northern Region.

The total invested value of irrigation, power, and flood control developments in the Columbia Basin today is approximately 2 billion dollars. It is estimated that installation of authorized and recommended developments would boost this investment to more than 7 billion dollars. Present invested value of similar developments in the Missouri Basin is about 1.9 billion dollars. Completion of projects under construction plus those authorized and recommended would raise this investment to more than 8 billion dollars. Thus the total value of water-handling facilities that are dependent in large measure upon clean, usable water from Northern Region watershed lands is now nearly 4 billion dollars, but will soon be over 14 billion dollars.

Of primary and recurring concern to people of the Columbia and Missouri River Basins are the problems of:

1. Controlling snowmelt floods, especially along main streams.

2. Preventing sediment in stream channels, reservoirs, water supply systems, irrigation structures, and on farm lands.

3. Improving late summer water supplies for irrigation.

4. Increasing winter streamflow for power generation.

5. Preventing local flash floods from high-intensity rainstorms.

These problems occur in large part because of wide seasonal fluctuations in streamflow. One obvious solution, of course, is large storage dams to regulate streamflow. The projects proposed for these two great rivers should pretty well provide a satisfactory solution for these problems insofar as downstream interests are concerned. Despite this, there are two problems that storage and streamflow regulation through big dams will not handle. One is continuing sedimentation with its attendant storage depletion and high maintenance costs. The other is the fact that large dams will not prevent flood discharges nor water shortages in upper watersheds above them where sizable investments exist in both rural and urban developments. To control floods in upstream reaches and to protect the life of downstream structures and the billions of dollars in industrial and agricultural activities dependent upon them, every effort is needed to control the amount, quality, and timing of streamflow from forest and range watersheds in the Northern Region.

Physical Characteristics of Watershed Lands in the Northern Region

The Columbia and Missouri Basins are vastly different hydrologically. About 70 percent of the Columbia Basin portion of the Northern Region receives more than 20 inches of precipitation annually; 40 percent receives more than 30 inches, and 4 percent more than 60 inches. By comparison, about 70 percent of the Missouri Basin portion receives less than 15 inches, and only 1 percent receives more than 20 inches.

Average annual runoff from the Columbia River side of the region is equivalent to about 14 area inches. This equals about 41 million acre feet, of which about 27 million originate on 17.8 million acres of national forests. Greatest runoff is from snowmelt in April, May, and June, which are also the months of greatest annual rainfall. About 2.5 area inches of average annual runoff is produced from the Missouri River side of the region. This amounts to about 17 million acre feet, of which about 6.2 million originate on 10.1 million acres of national forests.

About 54 million acres, or 46 percent of the region, are arid lands which ordinarily contribute less than 1 area inch of streamflow annually and this mostly as surface runoff. Ninety-eight percent of these lands occur in the Missouri Basin and are characterized by grass and shrub range, mostly in the plains section of eastern Montana, but also extending into parts of the headwater areas to the west.

Approximately 42 million acres, or 36 percent of the region, are semiarid, producing generally more than 1 inch but less than 10 inches of streamflow each year. These lands produce some seepage flow from snowmelt in the spring but contribute little other than surface runoff during the remainder of the year. About 60 percent of the semiarid

lands occur as foothills and low elevation mountains in the upper Missouri Basin, and are characterized partly by ponderosa pine and Douglas-fir forest. In the Columbia Basin these lands occupy substantial areas along the western fringe of the region and in the valley bottoms and low elevation mountains of the Clark's Fork and Flathead River drainages in western Montana. Here, as in the Missouri Basin, grass and shrubs, together with ponderosa pine and Douglas-fir forests, comprise the principal plant cover.

The real water-yielding areas in the region, occupying 18 percent of it, are some 21 million acres of humid lands which produce more than 10 area inches of runoff and which contribute nearly all of their streamflow as seepage flow throughout the year. Eighty-two percent of these lands are in the Columbia Basin, characterized mainly by white pine, larch, spruce-fir, and lodgepole pine forests. In the Missouri Basin they include the higher mountains in central Montana, where the main plant cover is mostly lodgepole pine forest and subalpine-grass-forb range.

Compared with the rest of the Station territory and with some other sections of the western United States, plant cover conditions on Northern Region watershed lands are generally favorable for controlling storm runoff and maintaining soil stability. In recent years substantial improvements in forest and range practices are leaving watersheds in better condition than formerly. Wildfire-burned area has been drastically reduced. Timber cutting has nearly doubled in recent years, but logging roads to harvest this timber are being built to higher standards, with increasing attention given to matters of location, design, and other items of precautionary or corrective nature affecting the control and disposition of water. Considerable progress has been made in livestock and big game adjustments on national forest ranges. However, numerous problems continue to arise from impacts of land use on water and soil. Most of these problems stem from the need for more effective operational measures that will maintain runoff control and soil stability under continued forest and range use.

Notwithstanding favorable plant cover and soil conditions on most watersheds in the Northern Region, there are forest and range areas on which the plant cover and soil have been damaged by past abuse and are not providing adequate watershed protection. These areas, though somewhat less extensive than elsewhere in the Station territory, present equally difficult problems of finding ways to restore control of storm runoff and a series of problems concerned with development of measures for mantle stability on depleted and eroding lands.

Another problem that is becoming continuously more important as industry and agriculture expand, is that of increasing local water supplies. One solution to this problem lies in research that will show how to increase the amount or improve the timing of water yields without seriously stepping up flood frequencies and magnitudes, or sediment loads.

Watershed Maintenance Problems on Forest Lands

In 1955 about 970 million board feet of timber were cut from national forests of the Northern Region and 830 million board feet from state and private lands. This harvest involved logging activity on some 112,000 acres, of which approximately 62,000 were national forest. It also involved building about 1,600 miles of truck and jammer roads and 1,000 miles of tractor roads. This is equivalent to an area of approximately 10,000 acres from which protective plant cover is annually and permanently removed. Ninety-five percent of the timber harvested came from Columbia River Basin watersheds. Increased logging activity necessary to reach allowable cut levels may well result in baring of soil on as much as 15,000 acres of new roads each year and disturbance of as much as 160,000 additional acres. Current logging and roadbuilding activity, not to mention probable future increases, present some specifically important maintenance problems on forest land.

1. How to lay out and construct logging roads so as to prevent or reduce soil movement into stream channels.

2. How to control drainage from road and skidtrail surfaces.

3. How to cut timber without increasing snowmelt peaks and sediment loads.

4. How to dispose of slash and other logging debris without increasing surface runoff and erosion.

Answers for such problems are most urgently needed in the higher water-yielding areas of the region where the hydrologic effects of timber cutting may have considerable influence on the magnitude of spring snowmelt floods. Of greatest importance in this respect are the white pine, larch, and spruce-fir forests of the upper Columbia Basin in northern Idaho and western Montana.

Watershed Maintenance Problems on Range Land

Approximately 81 percent of actual livestock grazing use on national forests of the Northern Region now occurs in Montana. Most of it is on watersheds of the upper Missouri Basin. These watersheds also receive additional use from large numbers of game animals. Though there have been reductions in grazing use, some of these ranges are continuing to deteriorate. Some progress has been made in recognizing signs of range-watershed deterioration on badly damaged areas, but there is need for better criteria of range condition and trend for areas which are not so obviously depleted. Required here is more specific knowledge about:

1. How much and what kind of plant cover and soil conditions are needed to cope effectively with high-intensity summer rainfall.

2. How much and by what methods these ranges can be grazed without losing control of storm runoff and soil stability.

Solutions for these problems are needed most urgently on high-elevation grass-forb range, on foothill sagebrush-grass range, and on low shrub-shortgrass range in the plains section in the Missouri Basin where intense rainfall occurs frequently.

Watershed Restoration Problems on Forest Land

The two most important activities that have contributed to forest watershed damage in the Northern Region are wildfire and poor road construction, the latter especially in connection with logging. Serious accelerated erosion is occurring on some burned areas, especially where the forest has suffered multiple fires. Active erosion also continues from overly steep, poorly located, and improperly constructed roads on some logging areas, even after operations have been completed for some time. These damaged areas need to be stabilized. To accomplish this research needs to learn:

1. What vegetational and mechanical measures are effective for controlling surface runoff and stabilizing soil in eroding burns and on bared road surfaces, cuts, and fills.

2. What the effects of such measures are on water yields and sediment production.

Solutions of these problems requires careful consideration of soils. The loess and granitic soils covering extensive areas of the upper Columbia Basin and the glacial silt soils covering large areas across the northern part of the region are most vulnerable to erosion in the absence of protective plant cover. Forest types having these soils and in which erosion problems are of prime concern are the white pine, larch, and spruce-fir.

Watershed Restoration Problems on Range Land

It is estimated there are more than 200,000 acres of native range on the national forests of the region and from 2 to 3 million acres outside the forests on which the perennial plant cover is so depleted that measures beyond mere protection from grazing are needed to restore them to satisfactory watershed condition. Research is needed to determine:

1. How to restore runoff control and soil stability by better grazing management methods, by artificial re-vegetation measures, and by application of mechanical control structures.

2. How watershed restoration measures affect streamflow peaks, water yields, and sediment.

The largest range area in the region for which such answers are needed is abandoned dry-farm land in the plains section of eastern Montana. Other critically depleted areas on which restoration effort is needed occur in the Missouri Basin headwaters on subalpine-grass-forb summer ranges characterized by dolomitic soils and on sagebrush-grass winter ranges on soft sediment and terrace soils.

Watershed Improvement Problems on Forest Land

Water shortages occur throughout the Missouri Basin in about one year out of ten. Shortages also exist locally in different parts of the Basin almost every year, principally because of large variations in winter precipitation and seasonal flow. Steep profiles of most streams that feed major tributaries in the upper Missouri Basin afford little opportunity for surface storage. Much early-season runoff is lost downstream, leaving upper Basin irrigation dependent upon inadequate summer and fall streamflow. There is need for not only increased supplies of water but, even more importantly, for improvement of streamflow timing to meet irrigation needs.

The best opportunity for creating watershed conditions favorable to improved summer water yields lies in forested watersheds at high elevations where a large part of annual precipitation is snow. Other opportunities exist in heavily forested or wooded streamside areas where large amounts of water are lost by transpiration processes. While it appears that cutting of forests and removal of riparian vegetation can bring about increased water yields, the magnitudes of increase in relation to the treatments required to produce them, and the extent to which timing of streamflow can be altered, are far from being known. It is important also to know whether streamflow peaks are increased in damaging amounts and also whether streamflow can be delayed in terms of weeks or only days. More specifically, research is needed to determine:

1. The best sizes of forest openings and patterns of timber cutting to increase water yield and delay time of streamflow.

2. The greatest amounts of timber that can be safely removed without increasing floods and sedimentation.

3. How, and to what extent, removal of riparian vegetation affects water yield and peak streamflow.

Solutions for these problems are most needed in the lodgepole pine and spruce-fir forests of the upper Missouri Basin.

Watershed Improvement Problems on Range Land

In view of the importance of snow as a source of water in the Missouri Basin, consideration must be given to possibilities for improving water yields from extensive areas of subalpine-grass-forb range that receive heavy snowfall each year. This range has received little attention as a possibility for water yield improvement by snow management and waterspreading structures. More knowledge is needed of:

1. How drift fences and planted windrows can best be employed for accumulating snow, slowing melt, and delaying streamflow.

2. How and to what extent streamflow from late-melting snowdrifts can be further delayed by waterspreading and storage in the soil mantle.

Considerable evidence indicates that water consumption by deep-rooted shrubs probably exceeds that of more shallow-rooted grass and herbaceous vegetation. Research is needed to determine:

1. How to convert a deep-rooted plant cover to a shallow-rooted one and maintain it.

2. How and to what extent conversion of deep-rooted vegetation to a shallow-rooted cover affects water yield and sediment production.

The lower-lying sagebrush-grass range, especially on deep terrace soils, appears to offer best opportunity for such studies.

Problem Priorities and Proposed Program

In summary, the most important watershed management problems and the problem areas on which research is needed, in order of priority, are as follows:

1. How to maintain control of snowmelt discharges and mantle stability under the impact of timber harvest cutting and/or grazing on:

    a. White pine forest lands having loess soil in the Columbia Basin.

    b. Larch forest lands having glacial silt soil in the Columbia Basin.

    c. Subalpine range having dolomitic soil in the Missouri Basin.

2. How to restore control of summer storm runoff and soil stability on:

    a. Subalpine range having dolomitic soil in the Missouri Basin.

    b. Sagebrush-grass range having soft sediment soil in the Missouri Basin.

    c. Low shrub-shortgrass range having hard sediment soil in the Missouri Basin.

3. How to increase summer streamflow without increasing damaging peak flow discharges or sediment on:

    a. Lodgepole pine forest lands having dolomitic soil in the Missouri Basin.

    b. Subalpine range having dolomitic soil in the Missouri Basin.

    c. Spruce-fir forest having dolomitic soil in the Missouri Basin.

Though research is needed on all of the problems and in all of the problem areas listed above, and an acceptable research program would involve studies on each, a somewhat more modest program of research must be settled for at this time. It is proposed to limit the program for the immediate future to the following efforts:

1. Initiate work in white pine forest including:

   a. Analysis of existing data on snow hydrology from Priest River Experimental Forest.

   b. Selection and reservation of experimental watersheds for future investigations.

   c. Plot studies of interception, evaporation, and melting effects on soil moisture regime.

2. Assist the Northern Region in development of guides for applying runoff and erosion control measures on roads and logging areas based on information currently available or to be collected by the region.

3. Develop plans for initiating water-yield studies in lodgepole pine forest, including:

   a. Selection and reservation of experimental watersheds.

   b. Plot studies on snow hydrology under various forest stand conditions.

4. Develop plans for a study of methods for restoring depleted subalpine-grass-forb ranges.

It is obvious that this proposed program does not provide for complete development and evaluation of management practices needed to meet desired watershed management objectives in even one problem area of the region. However, it should provide a foundation for more intensive effort as more adequate research facilities become available.

Streamflow Characteristics of a White Pine Watershed

Snowmelt is responsible for high spring volumes of streamflow from watersheds of the upper Columbia River Basin. Rapid melting of deep snow, especially when accompanied by heavy rainfall, permits large quantities of water to enter the soil mantle rather quickly. In some instances the amounts exceed the soil storage capacity and bleed out rapidly. Water thus released finds its way to stream channels more quickly than water that travels through the soil to deeper aquifers. This can cause floods. The Columbia River flood of 1948, one of the worst ever to occur in the Northwest, was caused in this way. Such flood-producing conditions can develop even on heavily timbered watersheds in good condition. To what extent the peak flood stages from such watersheds can be altered by timber harvest practices is a problem requiring research. Before these effects can be accurately evaluated, however, better knowledge is needed about the streamflow characteristics of timbered watersheds that are relatively undisturbed. A contribution to such knowledge was made during the past year by analysis of 16 years of streamflow records from Benton Creek, a 950-acre white pine forested watershed in northern Idaho, and one of the few, small gaged forest watersheds in the northern Rocky Mountains.

During the period of record, from 1939 to 1955, average annual precipitation on this watershed was 39.34 inches. Mean annual runoff during the same period was 14.93 inches and ranged from 6.01 to 21.70 inches. Instantaneous discharges ranged from a low of 0.104 to a high of 16.035 cubic feet per second square mile. Two-thirds of the runoff occurred in April, May, and June, and maximum instantaneous discharges occurred in May in all but three of the years of record.

Summer streamflow resulted almost entirely from ground water depletion, the effects of summer rains being negligible. Mean summer flow of 1.47 inches was only slightly more than the ground water discharge of 1.35 inches determined from normal depletion curves for this watershed.

A multiple linear correlation was developed relating annual streamflow to four variables: (W) winter precipitation, (F) spring and fall precipitation, (S) summer precipitation, and (R) antecedent September runoff, all expressed in inches. The equation derived was:

$$\text{Streamflow} - .983W + .722F + .144S + 27.92R - 23.56$$

Using this equation, the average annual streamflow from Benton Creek during the 44-year period, 1911 to 1955, is estimated to have been 25.0 inches.

During the summer and early fall, diurnal fluctuations in streamflow on the order of 2 percent of the daily discharge were created by variations in evaporation and transpiration rates of streamside vegetation.

Soil Disturbance from Timber Harvesting

Maintenance of soil mantle stability is a problem of increasing concern on the steep ponderosa pine lands of southwestern Idaho. Expansion of timber harvest activity is baring more and more of the loose granitic soil that characterizes this area. Baring of soil is usually accompanied by impairment of infiltration and, hence, by accelerated storm runoff and erosion. It is highly desirable to know how to harvest timber from these lands with a minimum of sediment production. Needed for this is knowledge of the amount of soil laid bare by different cutting systems and logging methods. Some information in this connection has been obtained from a study of ponderosa pine production in the Boise Basin Experimental Forest.

The amount of soil bared by harvesting timber from 35 logging compartments was closely related to the number and volume of trees removed. Timber was cut on some compartments by single tree selection and on others by group selection. With an increase in intensity of timber cut by single tree selection from 2,000 to 7,000 trees per square mile, the amount of soil bared increased from 46 to 131 acres per square mile. With similar increases in intensity of cut by group selection, the amount of bared soil increased from 34 to 89 acres per square mile. Greater dispersion of trees cut and less repeat usage of skidtrails is believed to be the cause of more bared area on single tree selection compartments.

In compartments cut by single tree selection and logged by small tractor, an increase in intensity of cut from 2,000 to 7,000 trees per square mile increased the area bared as haul roads from 38 to 112 acres per square mile. The amount bared as skidtrails, however, remained about constant at 12 acres per square mile. Under logging by large tractor, the amount of soil bared as haul roads was essentially constant at 26 acres per square mile regardless of intensity of cut; but increased cutting increased the amount bared as skidtrails from 31 to 96 acres per square mile.

In group selection compartments there was no significant differences in the amounts of area bared due to differences in tractor size. With increase in cutting intensity from 2,000 to 7,000 trees per square mile of soil bared as haul roads increased from 23 to 48 acres and, as skidtrails, from 20 to 45 acres per square mile.

These findings indicate that group selection timber cutting is superior to single tree selection for minimizing soil disturbance. Under group selection cutting it also appears that no particular advantage is gained by using one size of tractor in preference to another.

Control of Sediment from Logging Roads

The problem of keeping sediment out of streams flowing through forested sections of the Station territory is becoming acute, especially on the loose granitic soil in southwestern Idaho. Rapid extension of logging road systems onto steeper headwater lands has been attended by an increase in surface runoff and erosion from bared roadbeds and steep cut and fill slopes. Stepped-up deposition of sediment in stream channels points to a need for better road location and construction criteria to control runoff and maintain soil stability.

A previous annual report indicated that road gradient and length of slope on which runoff accumulates are critical variables affecting erosion on road surfaces. It also suggested some tentative standards for spacing of cross drainage on roads with granitic soil surfaces to prevent rill and gully erosion. Such measures, though generally adequate for this purpose, have not always been satisfactory for safely disposing of drainage water running from road surfaces. It was noted frequently that storm runoff diverted from road surfaces had sufficient eroding power to cut into fill or natural slopes below roads and to carry suspended material down these slopes for long distances. In some instances sediment emptied into stream channels; in others it stopped short of the channels, having been retarded or trapped on watershed slopes above the streams.

To develop better criteria for locating roads that will prevent sediment from reaching streams or other roads in a system, steps have been taken to examine and test the effects of roadway characteristics believed to exert influence on sediment movement. The characteristics that appear to have significant effect on the distance to which sediment can be carried below a road are the number of major obstructions below the road, the spacing between cross ditches on a road surface, the road gradient, and the embankment slope length. These factors have been combined into an equation for predicting sediment flow distances. Though further testing is needed, it is hopeful that this information will prove useful as a guide for determining the distance from a stream that a road can be safely located to control sediment.

WATERSHED RESTORATION

Effects of Plowing and Seeding on Subalpine Range

Depleted subalpine-herbaceous ranges continue to be a source of damaging summer storm runoff and erosion in numerous locations throughout the Station territory. In the past few years several range improvement projects have been initiated to increase grass production and to gain better control of runoff and erosion from such areas. One of these projects is located in the head of Manti Canyon on the Manti-LaSal National Forest. Here, 1,000 acres of moderately depleted range were closed to grazing in 1952 and treated by plowing and seeding. The area was protected from livestock grazing until 1956. Included in the treated area were paired one-half acre plots on several sites. One plot of each pair was not treated.

During the 3-year period following this treatment, total ground cover on the treated plots, including live plants and litter, did not change significantly from that on the untreated ones. The composition and volume of forage production, however, was drastically changed. There was about 5 times more grass and only 40 percent as much forb cover on the treated sites as on the untreated areas. Forage production on the treated sites (1,551 pounds per acre) was nearly twice that (848 pounds per acre) on the untreated ones.

Surface runoff, soil erosion, and infiltration rates on the treated sites were not significantly different from those on the untreated areas. However, on both kinds of sites, runoff and erosion decreased with increased amounts of ground cover. Infiltration rates were about twice as great on areas having above-average ground cover than on those with below-average cover. Additional tests are planned as it is expected there will continue to be further changes in the density of vegetation on the treated sites.

During the summer of 1956 the area was reopened to livestock grazing use. Grazing exclusion cages were installed on both treated and untreated areas. This will permit comparison of forage production and hydrologic characteristics under continued protection with these same characteristics under grazing use. It is hoped that findings from this phase of the study will prove useful as criteria for determining safe grazing use on this range.

Evaluation of Restoration Measures on Pleasant Creek Watershed

In 1955 the Manti-LaSal National Forest and the Soil Conservation Service cooperated on a watershed improvement project in the Pleasant Creek watershed in central Utah. The Station assumed responsibility for planning and supervising an evaluation study of the upstream improvement measures employed. The study was intended to determine the effects of protection from grazing, reseeding, and contour trenching on the forage production and hydrologic characteristics of subalpine-herbaceous, mountain brush, and pinyon-juniper range sites.

Prior to treatment, infiltrometer tests were made on these sites. They show definitely inverse relationships between amounts of ground cover and storm runoff and erosion. Ground cover on the subalpine-herbaceous plots averaged 70 percent. Runoff created by 3 inches of applied rainfall on these plots averaged 40 percent and eroded soil ranged from zero to 9,344 pounds per acre. On mountain brush plots ground cover averaged 23 percent, runoff was 62 percent, and eroded soil ranged from 472 to 10,518 pounds per acre. The most depleted plots were those on pinyon-juniper range where ground cover averaged 13 percent. These plots also produced the largest amounts of runoff and erosion. Runoff averaged 74 percent and eroded soil ranged from 977 to 14,372 pounds per acre.

Gully control runoff plots equipped with sediment basins have been installed on several paired areas. One of each pair was untreated, the other contour trenched to determine the effects on runoff and sediment where erosion has reached the gully stage. During the past year area-capacity measurements were made of the sediment basins. This sets the stage for periodic repeat measurements to evaluate the effects of such treatment on sediment production.

Cover Restoration on High Elevation Range in Idaho

On July 23, 1955 a violent flood discharge occurred in Sulphur Creek, a tributary of the Middle Fork of the Salmon River in Idaho. The flood originated on badly deteriorated subalpine range on the slopes of Morehead Mountain. During the past year the Boise National Forest has constructed many miles of contour trenches to control surface runoff from future storms likely to cause a repetition of this flood.

The Station is cooperating in the watershed improvement project in two ways: One is to determine the effects of various strengths of fertilizer application on ground cover production of the newly seeded trenches. The other is to determine the rate of plant recovery on strips of native range between contour trenches where grazing has been eliminated. Some strips were left to natural recovery,

some were fertilized, some reseeded, and some both reseeded and fertilized. Permanent line transects have been established to measure conditions of ground cover and plant composition on these strips at periodic intervals. Measurements prior to treatment show that the ground cover had been depleted to between 18 and 42 percent. Repeat measurements are scheduled for 1958.

WATERSHED IMPROVEMENT

The currently prolonged drought in the southern part of the Station territory has made an already acute water supply problem even more critical. It has focused attention on the need to reconsider all possible sources and means for obtaining more water, including increase of streamflow from mountain watershed lands. On the other hand, rapid expansion and mounting costs of water storage projects have aroused new concern about the need for preventing sedimentation by control of erosion on upstream watersheds. How to make more useful streamflow and, at the same time, maintain effective control of storm runoff and erosion on the same area pose difficult technical problems because the hydrologic conditions needed for these objectives are generally different. Chiefly involved are questions of how and to what extent, if any, plant cover requirements for maintaining soil mantle stability can be safely compromised with those required for increasing water yields. Several studies are currently under way on this problem.

Cover Depletion Effects on Water Consumption

Restoration of plant cover on flood-source areas in Parrish Creek basin of the Davis County Experimental Watershed appears to have reduced snowmelt discharges as well as prevented recurrence of summer rain mud-rock floods. During the past year a cooperative study was undertaken with the School of Forestry, Range, and Wildlife Management of the Utah State Agricultural College to find out how and why water yields from former flood-producing areas may be altered by restoration of plant cover. The study is designed to compare soil mantle moisture conditions on aspen, brush, and herbaceous sites now in a restored condition with comparable areas on which flood-source conditions will be recreated by removing or drastically depleting the vegetation.

Of interest, as well as importance, is the method that will be employed for obtaining soil mantle moisture data. These measurements will be made with a portable neutron scattering unit developed by the Soils Department at Utah State Agricultural College. This unit registers the concentration of hydrogen ions in the soil, which is largely dependent upon soil moisture content. Readings can be directly converted to soil moisture determinations to test the reliability of the neutron unit. This unit, if found accurate within necessary limits, will eliminate time-consuming manual soil sampling and will be especially useful in soil-moisture studies on rocky soils often found on forest lands.

Aspen Cutting Effects on Water Yield

Studies on Davis County Experimental Watershed have shown that removal of aspen forest may effect a saving of as much as 4 inches of water in the soil mantle by reducing transpirational consumption. A new study has been started on this watershed to determine the actual effects of such savings on amount and timing of streamflow. For this purpose, two aspen-forested subwatersheds of 137 and 218 acres in size have been selected. These two watersheds are being gaged to determine their relative streamflow characteristics in an undisturbed condition. When these relationships have been sufficiently well determined to permit prediction of streamflow characteristics on one from those of the other, the timber on one will be cut and streamflow measurements continued so that the effects of cutting can be evaluated.

Effects of Snowdrifting and Cover Condition on Streamflow

The acuteness of the water supply problem that has developed in south-central Utah has intensified research efforts to discover ways and means of improving water yields in that area. If water in the form of snow can be stored on high-elevation range watersheds in such a manner that melting is substantially retarded, it is reasonable to expect a lowering of spring peak runoff and a strengthening of later season water yields. Studies on subalpine range in central Utah show that trapping of snow into drifts behind fences is physically feasible and that drifts so induced persist for as much as 2 weeks longer than snow on adjacent undrifted areas.

A new study has been started on this type of range to determine the actual effects of induced drifting on streamflow. Two 300-acre watersheds on the rim of the Wasatch Plateau have been selected for this study. These two watersheds, previously equipped with flumes for recording streamflow, have been reequipped with weir sections to improve the accuracy of streamflow records. A detailed plant cover and soil survey has been made of these two watersheds as a basis for planning snowdrifting locations and evaluating the effects of different range cover conditions on interception and soil moisture storage characteristics. Normal snowdrifting on both of these watersheds is being observed and streamflow calibrated preparatory to applying snowdrifting measures on one of the watersheds for streamflow improvement.

B. Publications in scientific and professional journals, etc.

ANDERSON, I. V. 1956. Properties, uses, and production of Engelmann spruce (*Picea engelmannii*). Forest Prod. Jour. 6: 307-311.

Explains the rise in production of Engelmann spruce from about 35 million board feet per year to nearly 500 million resulting from salvage of major bug-infested areas; describes the properties and uses of this versatile species; and forecasts the future place of the species in the western timber economy.

BINGHAM, R. T., A. E. SQUILLACE, and R. F. PATTON. 1956. Vigor, disease resistance, and field performance in juvenile progenies of the hybrid *Pinus monticola* Dougl. x *Pinus strobus* L. Zeitschrift für Forstgenetik und Forstpflanzenzüchtung 5(4): 104-112.

Juvenile performance of 16 different hybrid progenies from controlled pollinations between blister rust-resistant selections of eastern and western white pines is discussed in detail. Hybrids usually showed definite hybrid vigor and less resistance to rust than corresponding intraspecies crosses. The degree of hybrid vigor and rust resistance of a hybrid progeny seems to depend upon the superiority of the individual parents chosen in making the cross.

BLAISDELL, JAMES P., and WALTER F. MUEGGLER. 1956. Effect of 2,4-D on forbs and shrubs associated with big sagebrush. Jour. Range Mangt. 9(1): 38-40.

Authors describe effects of 2,4-D spray, used for the control of big sagebrush, upon 38 forbs and 15 shrubs and trees occurring in sagebrush stands of eastern Idaho.

BLAISDELL, JAMES P., and WALTER F. MUEGGLER. 1956. Sprouting of bitterbrush (*Purshia tridentata*) following burning or top removal. Ecology 37(2): 365-370.

The amount and nature of sprouting of bitterbrush after burning and after top severance by cutting is discussed. Study suggests that ability of plant to sprout in certain areas is influenced both by genetic and environmental factors.

BOE, KENNETH N. 1956. Regeneration and slash disposal in lodgepole pine clear cuttings. Northwest Sci. 30(1): 1-11, illus.

Relationships of cutting, seed supply, and slash disposal methods to fire hazard reduction and seedling establishment on different seedbeds were studied in lodgepole pine clear cuttings for 5 years in central Montana. The main seed supply for regenerating clear cuttings is in the cones attached to the slash or scattered over the ground. Only small, uncertain amounts of seed were dispersed beyond 3 chains from the uncut timber edge into the clear cuttings. Large numbers of seedlings per acre and high rates of stocking were found on skidroads and on forest floor, scarified, and lopped and scattered seedbeds. Unburned slash windrows and other concentrations were moderately stocked while stocking on seedbeds resulting from burning of slash in piles and windrows was low. Of the four slash disposal methods tried--burning in windrows and concentrations, bulldozer piling and burning, lopping and scattering, and no disposal--only the first two reduced fire hazards to acceptable standards. Both of these methods are also satisfactory for regeneration providing burned spots are restricted to one-twentieth acre or less in area and cover no more than 25 percent of the total area cut.

CALHOUN, E. L., H. R. DODGE, and R. W. FAY. 1956. Description and rearing of Dendrophaonia scabra (Giglio-Tos) (Diptera, Muscidae). Ann. Ent. Soc. Amer. 49(1): 49-54.

The rearing of this fly in the laboratory is explained. The eggs, larvae, and pupae are described and figured.

COPELAND, OTIS L., JR. 1956. A study of the influence of certain factors on soil oxidation-reduction potentials. Dissertation abstracts, University Microfilms, Ann Arbor, Mich.

Effects of two moisture levels and two degrees of compaction on the oxidation reduction potentials of 17 soils over an incubation period of 8 weeks were determined. The "optimum moisture--no compaction" series maintained the highest and the "saturated-high compaction" series the lowest redox potentials throughout the incubation period.

COPELAND, OTIS L., JR. 1955. The effects of an artificially induced drought on shortleaf pine. Jour. Forestry 53(4): 262-264. (Note: Study completed before author transferred to Intermountain Station. Was not included in 1955 annual report.)

The experiment disclosed that a lack of soil moisture curtails diameter growth, shoot growth, and needle length, but needle color is unaffected. Reduction in crown density results in an over-all decrease in total nitrogen uptake. Branch dying, caused by a prolonged drought, eventually produces a much smaller crown than originally possessed by the tree.

COPELAND, OTIS L., JR. and ROBERT G. McALPINE. 1955. The interrelations of littleleaf, site index, soil, and ground cover in Piedmont shortleaf pine stands. Ecology 36(4): 635-641. (Note: Work completed in 1953, before senior author transferred to Intermountain Station. Was not included in 1955 annual report.)

This report reviews soil and plant cover conditions as determined by a soils-littleleaf survey of 158 Piedmont forest stands consisting mainly of second-growth even-aged shortleaf pine.

DODGE, H. R. 1956. Tussock moth threatens timber. West. Conserv. Jour. 13(1): 36, 40, 42-43, 45, 50.

The life history of the Douglas-fir tussock moth is described, the important outbreaks reviewed, and mention is made of current studies being undertaken to predict the trend of the current outbreak in northeastern Washington.

DODGE, H. R. 1956. New North American Sarcophagidae, with some new synonymy (Diptera). Ann. Ent. Soc. Amer. 49(2): 182-190.

Two new genera and four new species of sarcophagid flies are described. A key is presented to species of Chaetoravinia and several new synonymies are published.

DODGE, H. R. 1956. A new sarcophagid genus with descriptions of fifteen new species (Diptera). Ann. Ent. Soc. Amer. 49(3): 242-263.

The genus Idoneamima is created for 19 species of sarcophagid flies from eastern North America. Fifteen of the species are described as new, the others are removed from Sarcophaga. The male genitalia are figured and two keys to the separation of the species are presented.

DODGE, H. R. 1956. Two new Sarcophagid flies from Cuba (Diptera). (Intended for publication in "Revista de la Soc. Felipe Poe" in Cuba.) Memo de la Soc. Cubana de Hist. Nat. Vol. 23 No. 1: 97-103, illus.

Description of two new species of sarcophagid flies with figures is presented.

FOILES, MARVIN W. 1956. Effects of thinning a 55-year-old western white pine stand. Jour. Forestry 54(2): 130-132.

Thirty-year results indicated that light thinning had little effect on total volume production but enhanced the value of the stand by increasing the proportion of high-value white pine and by stimulating diameter growth of dominant and codominant stems.

HAUPT, HAROLD F. 1956. Nitrogen loss from granitic soils on cheatgrass brome range. Forest Sci. 2(4): 268-272.

Nitrogen content of the surface 0.5 inch of soil on cheatgrass brome range in south Idaho was found to vary directly with amount of plant and litter cover. Nitrogen losses caused by runoff from summer storms were greatest from depleted sites. Losses from sites disturbed by trampling were more than double those from undisturbed sites.

HOLMGREN, RALPH C. 1956. Competition between annuals and young bitterbrush (Purshia tridentata) in Idaho. Ecology 37(2): 370-377.

Control of competing vegetation on an annual-weed type was found to be requisite to establishment of artificially seeded bitterbrush on a deer winter range. Where the competitors were broadleaved summer annuals, growth rate of bitterbrush seedlings was reduced and first-season mortality much higher than on weed-free, but otherwise similar, sites. Where the competitor was the winter-annual cheatgrass, virtually all bitterbrush seedlings died within a few weeks after emerging.

HOLMGREN, RALPH C., and JOSEPH V. BASILE. 1956. Range re-vegetation and deer on the Payette. Idaho Wildlife Review 9(2): 10-13.

An important factor adverse to establishment of bitterbrush by artificial planting on a deer winter range is the deer herd itself.

LEAPHART, CHARLES D. 1956. Physiological studies of some fungi associated with pole blight of western white pine. Mycologia 48: 25-40.

The report gives the prerequisites of growth of five fungi, four isolates of Leptographium sp. and one isolate of Ceratocystis pilifera, isolated from pole blighted trees.

MARSTON, RICHARD B. 1956. Air movement under an aspen forest and on an adjacent opening. Jour. Forestry 54(7): 468-469.

Anemometer measurements made under an aspen forest canopy and on an adjacent grassy opening at 8,200 feet elevation showed that the aspen cover caused an average wind velocity reduction of 2.6 miles per hour and a relative reduction of 79 percent as compared to velocities in the open.

MIELKE, JAMES L. 1956. The rust fungus (Cronartium stalactiforme) in lodgepole pine. Jour. Forestry 54(8): 518-521.

Contains information on the fungus designed to aid in its field recognition. Nomenclature of the organism, its hosts, range, character of attack on lodgepole pine, and the damage caused by it are discussed.

PARKER, D. E. 1956. The effects of DDT on wildlife. Idaho Wildlife Review 8(16): 5-7.

A brief review is given of the background of research into effects of DDT on wildlife prior to its extensive use in controlling forest pests.

ROE, ARTHUR L. 1956. The effect of competition in old-growth western larch--Douglas-fir stands. Montana Acad. Sci. Proc. 16: 41-45.

Reports an attempt to investigate quantitatively the effect of root competition by the understory on an overstory of larch and Douglas-fir. Removal of the understory resulted in a significant increase of growth in the overstory western larch but not in the Douglas-fir. Effects of these results on management practices are discussed.

SCHOOF, H. F., E. P. SAVAGE, and H. R. DODGE. 1956. Comparative studies of urban fly populations in Arizona, Kansas, Michigan, New York, and West Virginia. II, seasonal abundance of minor species. Ann. Ent. Soc. Amer. 49(1): 59-66.

Records of abundance and months of occurrence of the minor species of flies trapped in the above-named states are presented.

SMITH, EDWARD W. III, ELBERT CLEAVELAND, and DONALD W. LYNCH. 1956. A guide for finding superior ponderosa pine trees and stands in southwestern Idaho. Southern Idaho Forestry Association, Inc.

Defines for laymen certain genetics terms; gives instructions for selecting and reporting "plus" ponderosa pine trees.

C. Processed reports.

ANDERSON, I. V. 1956. Engelmann spruce: Its properties, uses, and production. Research Paper 39, 16 pp.

Explains the rise in production of Engelmann spruce from about 35 million board feet per year to nearly 500 million resulting from salvage of major bug infested areas; describes the properties and uses of this versatile species; and forecasts the future place of the species in the western timber economy.

BASILE, JOSEPH V., and RALPH C. HOLMGREN. 1956. Artificial revegetation studies on depleted big-game winter ranges in Idaho. Job Completion Reports, Project W 111-R-2. Idaho Fish and Game Dept., 19 pp.

Cost of seeding bitterbrush on steep slopes; results of the bitterbrush seeding-depth study; a comparison of 3 chemicals as protectants of sown bitterbrush seed against rodent depredation; and effects of game on browse revegetation efforts are given.

BOE, KENNETH N. and DAVID TACKLE. 1956. Board-foot increment on residual ponderosa pine in Montana. Research Note 34, 7 pp.

A harvest cutting study established in 1932 in western Montana relates board-foot growth to three different levels of reserve in mature ponderosa pine on Site Index 70. Twenty-year records disclose that 4,000 to 8,000 board feet per acre of vigorous, well-spaced trees between 120 and 220 years old and of moderate size, comprised a satisfactory reserve. A table showing individual tree growth during the 20-year period by diameter, vigor, and intensity of cutting is presented for ponderosa pine and Douglas-fir.

COLE, W. E. 1956. Biological observations on the pine butterfly during an outbreak in southern Idaho, 1953-1954. Research Note 29, 8 pp., illus.

Observations on the life history and habits of the pine butterfly are given and descriptions and illustrations of different developmental stages are presented.

COLE, W. E. 1956. Surveys and control methods of the pine butterfly during an outbreak in southern Idaho, 1953-1954. Research Note 30, 9 pp. and map, illus.

Methods are described for sampling populations of pine butterfly prior to aerial spraying and for determining mortality following spraying.

COPELAND, OTIS L., JR. 1956. Watershed management in research-soil survey needs. Proc. Watershed Management Conference, Northern Region, pp. 36-43.

A discussion of the needs for and the interpretation and utilization of soil survey information in relation to watershed management, engineering, timber management, and other activities.

COPELAND, OTIS L., JR. 1956. Preliminary soil-site studies in the western white pine type. Research Note 33, 4 pp.

The results indicate a strong relationship between certain easily determined soil characteristics and site index of western white pine. The significant relationships between site index of commonly associated species in the white pine forest type also provide means for estimating the probable site index from other species on the same site.

CRADDOCK, GEORGE W. 1956. Status of present knowledge and present watershed research program of the Intermountain Station. Proc. Watershed Management Conference, Northern Region, 106 pp.

Discusses and presents diagramatically the kind of knowledge that has been developed so far in watershed management research and specifically how that knowledge is applicable to forest and range lands of the Intermountain Region. Also reviews current watershed problems and research programs in the Region 4 portion of the Station territory.

DIVISION OF FOREST ECONOMICS. 1956. Economics research needs related to wild land management and development in the mountain states. Research Paper 38, 27 pp., illus.

A review of resource problems in the Rocky Mountain States that warrant economic analysis is given. Covers individual problems in timber, range, water, and wildlife management. Problems in marketing and area management are also covered. Contains a general description of the whole area and briefer descriptions of each problem.

FOILES, MARVIN W. 1956. Time required to prune crop trees in the western white pine type. Research Note 32, 4 pp.

Summarizes the time required to prune crop trees in two western white pine stands and one mixed stand dominated by grand fir. The average production ranged from 37 trees per man-day in a fairly open white pine stand to 16 trees per man-day in a dense, brushy, mixed stand.

HERRINGTON, ROSCOE B. 1956. Montana Christmas tree shipments drop slightly. Research Note 28, 4 pp.

Gives numbers of Christmas trees shipped from various Montana counties by rail and truck, and numbers shipped to most important state markets. Also, shipments are compared with previous years.

HERRINGTON, ROSCOE B. 1956. Northern Rocky Mountain pole production in 1955. Research Note 37, 4 pp.

Numbers of poles produced in 1955 in Montana, north Idaho, and northeast Washington are presented. Production by species and source is also given. Proportions by length and A.S.A. class are shown. Comparisons are made with production in previous years.

ISRAELSON, MARGUERITE A. 1956. Publications of the Intermountain Forest and Range Experiment Station, 1953 through 1955, and the Northern Rocky Mountain Forest and Range Experiment Station, 1951 through 1954. Research Paper 29 (Supp.), 35 pp.

This supplement brings up to date as of 1955, the publications of the consolidated Stations.

MIELKE, JAMES L. 1956. A needle cast of lodgepole pine caused by the fungus *Hypodermella concolor*. Research Note 27, 3 pp.

The fungus is now epidemic and spreading in the Intermountain region. Its distribution, hosts, symptoms, life history, and character of damage are briefly outlined.

MOESSNER, KARL E. 1956. Combined vertical and horizontal stereograms. Research Note 36, 3 pp. illus.

Presents a series of stereograms of forest conditions combining vertical aerial views with horizontal pairs taken with a stereo camera. Describes how to prepare these stereograms.

MOESSNER, KARL E. 1956. A parallax wedge for mountainous areas. Research Note 39, 2 pp. illus.

Presents a new parallax wedge for measuring heights on aerial photographs of areas of large elevational variations.

MOESSNER, KARL E. 1956. Aerial photo scale-protractors for mountainous areas. Research Note 40, 7 pp. illus.

A redesign of aerial photo protractors to give a range of scales more suitable for use on photography having wide variations in scale as well as providing a more readable protractor is presented.

MUEGGLER, WALTER F. 1956. Is sagebrush seed residual in the soil of burns or is it wind-borne? Research Note 35, 10 pp.

Concludes that sagebrush seedlings on burned areas arise both from seed introduced from adjacent unburned sources and from seed stored in the soil that remains viable after burning. Residual seed appears to be the greater source of seedlings on the major portion of large burns.

PACKER, PAUL E. 1956. Watershed management problems and research needs in the Region 1 area. Proc. Watershed Management Conference, Northern Region. 106 pp.

Presents a preliminary analysis of watershed management problems and delineates important problem areas in northeastern Washington, northern Idaho, and Montana. Characteristics of Region 1 watershed lands giving rise to problems are discussed and kinds of research needed to provide solutions are suggested.

PLUMMER, A.PERRY, and ROBERT L. JENSEN. 1956. Artificial revegetation studies on big-game ranges in Utah. Job Completion Reports, Project W 82-R-1. Utah Fish and Game Dept., 26 pp.

Growth and survival of shrub plantings using planting stock, wildings, stem cuttings, and seedling transplants; seed acquisitions, site classification; germination techniques; and methods of site preparation and planting are included. Gives results from March 1, 1955 to March 1, 1956.

TACKLE, DAVID. 1956. Stocking and seedbed distribution on clean-cut lodgepole pine areas in Utah. Research Note 38, 3 pp.

Reproduction and seedbed distribution were sampled on 6-year-old clean-cut areas in the Uinta Mountains of northeastern Utah where the logging slash had been lopped, scattered, and left unburned. Adequate stocking of lodgepole pine occurred only on seedbeds classified either as slash under 1 foot deep, disturbed duff, or disturbed mineral soil. Seedbeds not conducive to seedling establishment were slash over 1 foot deep, undisturbed duff and soil, and grass and brush. The study substantiates earlier observations that burning of slash is not essential for successful establishment of lodgepole pine on clean-cut areas.

TAYLOR, ROBERT E. 1956. Some properties of 144 soils from three Intermountain States. Misc. Pub. 7, 15 pp.

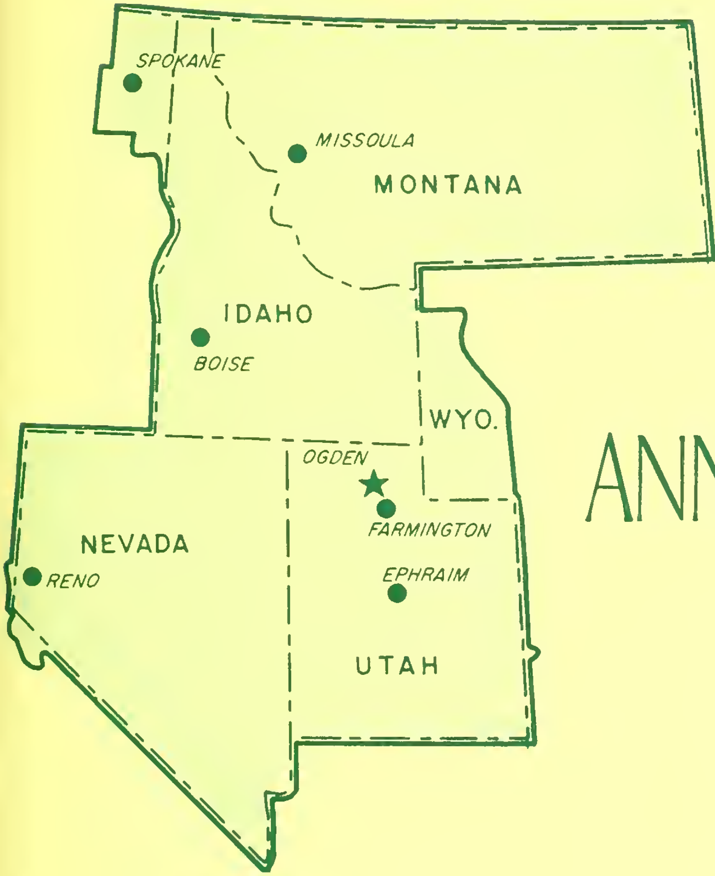
Presents basic data on the chemical and physical properties of 144 soils from Utah, southern Idaho, and eastern Nevada. Properties were determined from bulk samples and 2-inch cores in the upper 18 inches of the mantle. Properties tested included mechanical composition, organic matter, stone content, free carbonite content, pH reaction, and plasticity constants.

WASHBURN, R. I. 1956. Electronic recorder as aid in aerial insect surveys. Research Note 31, 3 pp., illus.

Reports on tests of a dictating machine used in aircraft during aerial insect surveys with description and illustrations of equipment.

WILSON, ALVIN K. 1956. The Boise Basin Experimental Forest for better forest management. Misc. Pub. 8, 26 pp., illus.

A guide book which outlines past and current research activities on the experimental forest.



ANNUAL REPORT 1957

INTERMOUNTAIN FOREST & RANGE EXPERIMENT STATION

FOREST SERVICE
U. S. DEPARTMENT OF AGRICULTURE

OGDEN, UTAH

REED W. BAILEY
DIRECTOR

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CONTENTS

INTRODUCTION

This annual report of the Intermountain station's activities during 1957 chronicles progress in research made by each of the several divisions. The staff has been alert to the extremely varied demands for study of the numerous problems related to wise management and maximum use of wild land resources of the station's territory. Accounts of research by the several divisions indicate the measure of the year's achievement. For details of this achievement you are invited to study the several sections of this report.

One activity that has been generally engaged in by the station has produced results that are only partially developed in the report. Nevertheless, this activity is fundamentally important to sound, valid, efficient programing: I refer to problem analysis. Its importance stems from the fact that it at once results from and is conducive to enlarged understanding--the most important achievement of scientific research.

In problem analysis no plots are measured, no data sheets are filled; but facts already gathered are assembled, carefully scrutinized, evaluated, and related to each other and to the whole problem. Problem analysis provides comprehensive appraisal of resources and their interrelations, of the processes of analysis, synthesis, and continuing appraisal, increasingly better understanding emerges. Reports dealing with problem analysis will be issued during 1958.

Reed W. Bailey

Director.

FOREST MANAGEMENT RESEARCH

The level of forest management varies widely over the 37 million acres of commercial forest land in the area served by Intermountain station. In parts of this area the forest manager is breaking into virgin stands with initial developments. Here he must solve a myriad of problems in converting wild forests to some semblance of management. In other parts of the area, the virgin forests have long since been logged over. There forest management may already be well on the way to a fairly high level. The manager is concerned with problems of obtaining maximum production and utilization from young forests.

This wide range in level of forest management requires an equally wide range of effort in forest management research. However, the problems needing research are so many that the station can tackle only part of them. This imposes responsibility to place our research effort where it will most help the forest manager. We are faced with decisions in placement of research effort between studies that will increase forest production during the next half century and with studies concerned with planting, natural regeneration, and genetics, which will increase forest production only in the very long run.

The present program has aimed for balance. We are engaged in studies of natural regeneration throughout the station area because keeping forest land productive is the first responsibility of any forest manager. Where natural regeneration is most difficult, we are studying methods of planting, with promising results. We have a wide variety of studies concerned with growing stock: how to manage it, build it up, and improve its quality. We are also concerned with genetic improvement of western white pine and ponderosa pine forests.

During 1957 significant progress was made. A cooperative agreement was reached with the University of Idaho for establishment by the Forest Service of a genetics unit at the university. Progress in forest genetics was also marked by hiring of a geneticist, Dr. Lawrence Inman, by the University of Idaho. Stationed at the Boise Research Center, he is developing a better ponderosa pine.

Two items of progress concern our experimental forests. The Bear Run Unit, a 1,200-acre tract of even-aged young ponderosa pine, was added to the Boise Basin Experimental Forest in southern Idaho. This will permit needed studies there in management of second-growth stands. During 1957 logging got under way on the Piquette Creek Experimental Forest in western Montana. This logging begins a program of cuttings that will test various silvicultural and beetle-risk markings, and will provide the experimental forest with a system of utilization roads.

Significant, too, were the close working relationships throughout the station area of forest management research personnel and forest managers in both public and private service. On-the-ground meetings and discussions are bringing the results of research into practice.

The following selected items portray the wide range of effort in forest management research at Intermountain station.

REGENERATION

Studies at Boise Basin Experimental Forest

Studies in artificial regeneration of ponderosa pine on the Boise Basin Experimental Forest were continued during 1957. Further tests of planting by digging holes with a powered auger were tried on four aspects. The importance of tamping was apparent again, and the relative thoroughness exercised by individual planters, as revealed by survival of their plantings was statistically significant. This fact emphasized the need for adequate training of planting crews. Plant competition on this experiment was reduced by hand scalping, which appears to have only doubtful merit in aiding survival of planted trees. These tests showed that 2,000 16- to 18-inch holes could be dug easily per day by two men in ground relatively free of stones using a 5-20 Homelite saw equipped with a power take off.

A start was made on outplanting of ponderosa pine in containers. One study tests two kinds of containers and seasons of planting. Sufficient seedlings were raised in various containers to permit a large-scale test of two methods of planting on three types of ground preparation on two aspects.

Elimination of plant competition to increase survival in plantations is important in regeneration in the ponderosa pine type. Applications of 2,4,5-T to planted areas having a heavy growth of brush, and 2,4,5-T and Dalapon to typical areas of ceanothus and sedge to be planted later, were made and considered successful. This latter test will be followed by site preparation and planting.

Ponderosa Pine Plantations in the Western White Pine Type

When it became evident that blister rust would preclude growing of white pine in many areas in the western white pine region, foresters naturally turned to a valuable species that could be grown on white pine sites. Ponderosa pine seemed to be a possible substitute. Though it was not abundant on the sites normally occupied by white pine, scattered individuals having good form were common even deep within the type. Consequently ponderosa pine was used in reforesting some areas of the white pine type during the early 1930's. Some plantations have grown poorly, possibly because stock used was grown from seed collected in localities having climates differing greatly from those of the areas planted.

A small test planting of white pine from Kaniksu National Forest and of ponderosa pine from Bitterroot National Forest was made in 1937 on Deception Creek Experimental Forest. The species were planted both pure and in mixture on a south slope. Brush competition has been severe. For the first 10 years the trees were all but hidden by ceanothus brush, but since 1947 growth of both species has been good.

First-year survival of white pine was 80 percent as compared to 60 percent for ponderosa pine. By 1942, survival of both species had declined to 50 percent. Since then ponderosa pine mortality has been somewhat more severe than that of white pine. Twenty years after planting, 41 percent of the white pine and 34 percent of the ponderosa pine are surviving.

The height growth rate of ponderosa pine exceeded that of white pine for the first 10 years. Since then, however, white pine has grown faster than ponderosa. At the age of 17 years the average heights of the two species were the same, but at 20 years the average height of the white pine was 16.8 feet compared to 14.6 for ponderosa pine. Height growth of ponderosa pine has been quite uniform over the entire 20-year period. The white pine growth rate, however, has increased during each remeasurement period.

Many ponderosa pines on this steep hillside have been deformed by the downward movement of the heavy snow-pack, but the white pines show very little deformity.

Growth of ponderosa pine planted in different densities of ceanothus brush was investigated in two plots on a west slope of the Priest River Experimental Forest. Survival 15 years after planting on the plot rated as having a 75-percent cover of brush was 21 percent. On the plot designated as having a 25-percent brush cover, 57 percent of the seedlings survived. On both plots, trees in the open survived equally well, but trees in the brush survived better on the plot having the lesser coverage of brush.

Twenty-one years after planting, the trees had suppressed the brush. Subsequent high mortality from unknown causes on the plot that had 25-percent coverage of brush has largely negated the early differences due to brush competition.

Results from the Deception Creek and Priest River ponderosa pine plantations on white pine sites show that while early growth of the trees may be good, their vigor and growth subsequently decline. It is believed, however, that ponderosa pine can be grown successfully on certain white pine sites if care is used in selecting the seed source of the trees to be planted.

Natural Regeneration in the Western White Pine Type

Natural regeneration is generally prompt in the western white pine type on all except the most severe aspects. Twenty years of reproduction records on Deception Creek Experimental Forest following various types of harvest cutting on a wide range of aspects attest the ease of obtaining natural regeneration on good sites and demonstrate the delays that may face the forester on the more severe exposures.

Reproduction on these areas has been measured periodically using a strip-transect method, tallying reproduction on a 4-milacre quadrat basis. A 4-milacre stocking of 65 percent, equivalent to about 1,000 trees per acre, is considered satisfactory.

On the northerly exposures studied, all even-aged silvicultural systems resulted in stocking of all species in excess of 90 percent by the tenth year following logging. Stands cut under a shelterwood system restocked most quickly. Four years after cutting, all shelterwood areas were stocked better than 65 percent, and by the seventh year exceeded 90 percent. Strip clear-cutting on these moist sites has reproduced a stand almost as effectively as the shelterwood system. While stocking on the latter lagged for the first 4 years after logging, it increased to more than 90 percent by the seventh year.

Reproduction has been less rapid on similar cuttings on southerly slopes. From 15 to 20 years have been needed for stocking on most south slope shelterwood and clear-cut areas to build up to a satisfactory level. Pure white pine shelterwood stands on steep south and southwest aspects average 70 percent stocking for all species and 26 percent for white pine 20 years after cutting. On more gentle southerly slopes adequate stocking to all species was fairly prompt and is above 90 percent after 20 years; but white pine stocking is inadequate, with only 40 percent of the 4-milacre units stocked.

Clear-cut strips on steep south slopes have become well stocked to all species in 15 to 20 years, but are only poorly stocked with white pine. Regeneration of a seed tree area having a westerly aspect has met similar delays. Stocking of all species in this area was inadequate when the reproduction was tallied 20 years after logging.

Delay in obtaining reproduction on these severe aspects is further complicated by the fact that the trees now established have a very healthy, dense brush cover as competition. Consequently they probably will grow slowly until they emerge above the brush. In the south-slope shelterwood stands special measures may be needed to establish a stand of white pine equivalent in stocking and composition to those that existed prior to cutting.

Stimulating Cone Production on Ponderosa Pine

A study to determine the effects of girdling and release on cone production of ponderosa pine was started in 1954 on the Bitterroot and Lolo National Forests in Montana. Total number of mature cones by stand age classes and treatment, based on five trees in each category, in first and second crops following treatment is shown in the following tabulation. Both partial girdling and complete knife girdling were exceptionally effective on young (Keen Class 1) trees the first crop following treatment, but the effect dropped off considerably for the second crop.

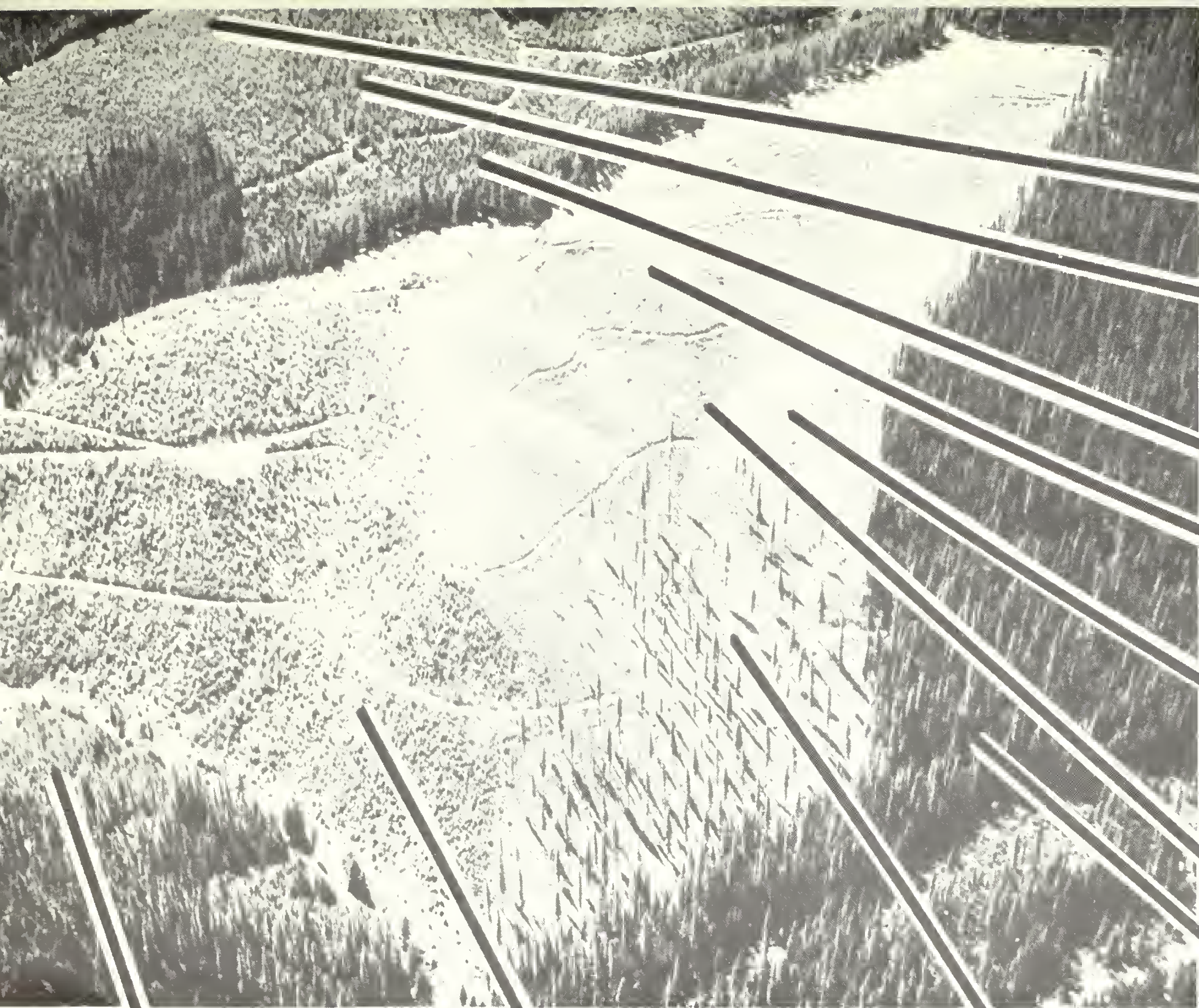

Figure 1.--Aerial view of a part of the Deception Creek Experimental Forest in northern Idaho. This experimental forest is devoted to research in the management of western white pine forests.

Keen age class	Cone crop	Partial girdle		Knife cut continuous girdle[1]	
		Treated	Check	Treated	Check
		Number	Number	Number	Number
1 (50 years)	1st	108	1	106	4
	2nd	14	1	1	1
2 (140 years)	1st	365	316	-	-
	2nd	570	369	-	-
3 (220 years)	1st	633	380	-	-
	2nd	612	224	-	-

1/ Age classes 2 and 3 not treated.

While the partial girdling of immature (Keen Class 2) and mature (Keen Class 3) trees appears to have had favorable effect on both first- and second-year cone production, the differences in production between the treated and untreated trees are not statistically significant.

Thus far, release of trees by thinning and by harvest cutting has not increased cone production.

Observations are being continued to determine possible delayed effects of all the treatments.

Natural Regeneration in the Ponderosa Pine Production Study, Boise Basin Experimental Forest

Since a good crop of ponderosa pine seed is expected in the fall of 1958, site preparation to assist natural regeneration on clear-cut groups of the ponderosa pine production study was started in 1957. Production study plans call for scarifying the soil to prepare a favorable seedbed on clear-cut openings just prior to a good seed crop. However, some openings are too steep to be scarified by a tractor without creating a serious erosion hazard. Some of these steep, erodible sites were treated in the fall of 1957 by a method designed to expose mineral soil and eliminate competition without increasing the erosion hazard. A TD-14 tractor with a dozer blade constructed a series of contour strips through the openings. These contour strips were made level or slightly insloping to prevent erosion, to collect moisture, and to change the angle at which the sun strikes the soil surface. The remaining clear-cut openings will be scarified by a hydraulic ripper attached to a crawler tractor in the summer of 1958. If this combination of site preparation and adequate seed does not restock the openings satisfactorily, they will be planted.

INTERMEDIATE CUTTINGS

Lick Creek Study Verifies Pruning Guides for Montana Ponderosa Pine

The Lick Creek study, based upon a paired tree experiment, was designed to investigate effects of crop tree release and pruning. The test, located in Lick Creek drainage on the Bitterroot National Forest, consists of four height-of-pruning classes with 15 pairs of trees in each class. One tree of each pair was randomly selected for treatment. Treatment consisted of removing competing trees to provide a 3- to 6-foot clear space around the crown of each treated tree, and pruning to remove one of the following proportions of live crown: 0, 25, 50, and 75 percent. The study permits a determination of effects of release with no pruning and with three heights of pruning. The trees were dominants in the 4- to 9-inch d.b.h. class and had an average age of 44 years.

Five-year results of the treatments are shown as follows:

Proportion of live crown removed	Five-year growth Inches
None	0.678
1/4	.585
1/2	.526
3/4	.380
Check trees	.617

Although the data show a slight increase in d.b.h. growth on the released trees with no pruning over the check trees, the difference is not significant statistically. Some individual trees showed a marked response to release but others did not. The next 5-year period may show better growth response after the trees have had a longer period in which to take advantage of the additional growing space provided by the release.

A considerable reduction in d.b.h. growth resulted from crown removal in pruning, particularly in the severely pruned trees. Growth of trees in all degrees of pruning varied significantly from that of trees released only. These findings confirm those from California and Oregon studies. In fact, in percentages the studies agree very closely. However, in the Lick Creek study reduction in height growth of the pruned trees was not significant. The response of height growth may not be immediate, but the next 5 years may show a significant effect.

Mortality was insignificant even among the severely pruned trees, for only two trees in the experiment died: they were attacked by insects.

In setting up a guide for pruning it is necessary to determine how much growth reduction one is willing to accept for the sake of quality. One inch per decade for trees in closed stands and under the kind of residual stand

found on the study area can be considered reasonably good growth. Removing up to one-half of the live crown on the study trees failed to reduce growth below this point. However, the crown ratio was reduced to less than 30 percent; this condition could leave the tree in a vulnerable condition. Consequently, a rule of removing not more than one-third of the live crown and retaining a crown ratio of not less than 40 percent should be adequate to retain sufficient crown for reasonably good growth.

Timber Stand Improvement on Boise Basin Experimental Forest

Timber stand improvement following logging on the ponderosa pine production study was continued in 1957. The working plan provides for thinning and improvement cutting in sapling and pole stands followed by crop-tree pruning.

Approximately 80 crop trees per acre were pruned during 1957 on two compartments thinned in 1956. Pruning time studies on these compartments revealed that the crew pruned an average of 25 crop trees per man-day. Height of pruning was about 18 feet.

Three additional compartments were thinned in 1957 according to plan. Thinning methods applied to various compartments of the production study include two intensities of crown thinning and two intensities of thinning from below. Sample plots were installed in each thinned compartment to give information on growth and yield following the four thinning treatments.

MENSURATION

Height-Over-Diameter Curves

Good height-over-diameter curves can be obtained by fitting a straight line to the data on semilogarithmic paper. This method has a distinct advantage over the more tedious method of fitting parabolic curves by least squares. A. Stoffels and J. Van Soest[1/] in the Netherlands made a study of the various mathematical formulae in use there for fitting height-over-diameter curves. They found that data on Japanese larch and Douglas-fir could be transformed into a straight line relationship when the log of d.b.h. was used, and a simple linear regression line could then be computed. Furthermore, they recommended fitting a freehand, straight line to the data plotted on semilogarithmic paper.

Some comparisons were made between the method of fitting a parabolic curve by the method of least squares and simple linear regressions transforming the data by using the log of d.b.h. Data from ponderosa pine on the Custer National Forest; from lodgepole pine in eastern Montana; from western larch, Douglas-fir, and alpine fir in western Montana; and from Engelmann

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1/ Stoffels, A., and Van Soest, J. Principele Vraagstukken Bij Proefperken 3. Hoogte regressie (with English summary). Nederlandsch Boschbouw Tijdschrift 25(7-8): 190-199. 1953.

spruce and alpine fir in northern Idaho were used in the comparisons. Standard error of the estimate was computed for each curve fitted by both methods. The data and the computed curves were also plotted to observe the fit. Logarithmic curves fitted the data nearly as well as--better in some instances--the parabolic curves.

The logarithmic curve has the advantage of simpler computational methods. For most purposes the data can be plotted on semilogarithmic paper and a freehand straight line fitted to the points. The linearity of the data can be observed when plotting the points on semilogarithmic paper. If the data appear to be curvilinear, the parabolic curve may give a smaller standard error of the estimate and therefore represent a better fit. However, in the data studied the relationship was linear when transformed by use of logarithms of d.b.h., and curves by the simpler method fitted the points as well. Where large numbers of height-over-diameter curves need to be fitted by objective methods, the logarithmic curve saves much time.

Lodgepole Pine Growing Stock Study

During 1957 the station started a new study on a problem which is of vital concern in the silvicultural management of lodgepole pine; namely, optimum stocking. This study is the first phase of an attempt to determine stocking levels for best growth in pure, even-aged stands of different age classes up to about 120 years. An interim goal is the preparation of improved site classification and yield tables for this species.

The first step in this study is establishment of a series of small permanent plots in lodgepole pine stands with a wide range of density and growing on areas of different site quality. Most of the plots are to be located on national forest land in Montana east of the Continental Divide. Supplementary data may be gathered from national forest lands in western Montana, western Wyoming, and eastern Idaho. First plot installations are being made on the Lewis and Clark National Forest in age classes 21-30, 71-80, and 81-90 years.

Because a similar problem exists for western larch, much of the knowledge gained in this study will be valuable in extending study to larch.

Board-foot Growth of Ponderosa Pine Following a Second Cutting

Studies in western Montana provide preliminary growth estimates for ponderosa pine following a second harvest cutting. The area in which the second cut was made is a 223-acre tract on the Bitterroot National Forest in Montana's earliest Forest Service selectively logged ponderosa pine stand. The initial cut was made about 1909. Average site index is 74 feet at 100 years. Table 1 shows the net annual growth per acre by reserve stand volume after the second cut.

Growth was best after the second cut where the largest reserve stand was left, as was expected. A similar relationship between reserve volume and growth has been found in many other ponderosa pine studies following initial cuttings.

Table 1.--Average annual growth per acre by reserve stand volume during 5-year period following second cutting

Reserve stand volume	Residual timber 1/ Growth	Residual timber 1/ Mortality	Ingrowth	Net annual volume growth per acre
Bd. ft.	Bd. ft.	Bd. ft.	Bd. ft.	Bd. ft.
2,031	106	5	47	148
5,768	117	0	28	145
8,000	97	8	11	100
12,441	231	3	8	236
2/ 8,121	3/ 133	5	4/ 16	144

1/ Trees 9.6 inches and larger.
2/ Weighted average on 223.3 acres.
3/ About 20 percent in Douglas-fir.
4/ About one-half of ingrowth on Douglas-fir.

Ingrowth varied inversely with reserve volume. The less the reserve volume, the greater the amount of ingrowth. This relationship reflects the treatments given the stand in both the first and second cuttings. Most of the ingrowth during the recent 5-year period is in trees that became established after the initial cut; the second cut provided the release needed for sustained rapid growth. Younger trees also have responded well to release; for this reason a virtual wave of ingrowth can be expected during the next 10 to 15 years. The low mortality throughout the area shows that reserve trees were properly selected.

The stand is in excellent growing condition and during the next 15-year period, after which a third cut is planned, should continue to add board-foot volume at a rapid rate.

Near-Merchantable Ponderosa Pine Trees are Produced by Plantations in 50 Years in Western Montana

Data collected during a recent cooperative porcupine damage survey of ponderosa pine plantations in Region 1 provided opportunity to study the growth of crop trees. Since the survey included only crop trees, full stand stocking information is not available. However, the progress of crop trees is interesting to foresters in assessing the future sawlog production in plantations. Stocking, on the basis of the survey, can be considered moderate. The point system was used to select crop trees for examination, and on this basis at least 100 to 140 well-distributed crop trees (mostly dominants) are present. The plantations were classified as to site index, and curves of average diameter and total height of trees were made.

Table 2 presents average total heights and diameters of crop trees by age of plantation and site index. On sites of index 70 the crop trees are just entering the 11-inch d.b.h. class 50 years from planting.

Table 2.--Average diameter breast high and total height of crop trees by age of plantation and site index (western Montana)

Age (years)	Site index 40		Site index 50		Site index 60		Site index 70	
	Diameter	Height	Diameter	Height	Diameter	Height	Diameter	Height
	Inches	Feet	Inches	Feet	Inches	Feet	Inches	Feet
15	--	--	0.6	5	0.8	5	0.9	6
20	1.3	7	2.0	9	2.7	11	3.2	14
25	2.2	9	3.2	13	4.1	16	4.8	20
30	2.9	11	4.1	16	5.2	21	6.2	26
35	3.5	13	4.9	18	6.2	24	7.4	32
40	4.0	15	5.6	20	7.2	27	8.5	36
45	4.3	16	6.2	22	8.0	30	9.6	40
50	4.6	18	6.7	24	8.8	32	10.6	42

Standard error of estimate: D.b.h. = 0.831 inch
Total height = 2.5 feet

We could, assuming 60 percent as much diameter growth for the next 50 years, expect that at age 100 years[2] the crop trees will average at least 16 inches in diameter. If we assume that an average of 100 crop trees per acre survive until that time, the volume in 100 years would be about 15,800 board feet. This is slightly larger than the 13,100 board feet shown in the normal yield tables[3] for site index 70 at 100 years.

The average crop tree diameters reached in the lower site classes by age 50 years are considerably smaller; consequently these trees will require longer time to reach merchantability. Thus, where plantations are made primarily for timber production, reliable methods are needed for selecting planting sites to assure good volume production within reasonable rotation periods.

2/ 100 years has been selected as a reference point only and should not be construed as a recommended rotation age.

3/ Meyer, Walter H. Yield of even-aged ponderosa pine. U. S. Dept. Agr. Tech. Bul. 630, 60 pp., illus. 1938.

Growth of Western White Pine Plantations

Ten years of growth records on two sets of plantation plots located on the Coeur d'Alene National Forest show that, on the average, plantations of western white pine are producing in excess of what could be expected from fully stocked natural stands on similar sites. The sample plots include one set in a stand 36 years old from seed with site indices ranging from 60 to 85, and another set in a stand 43 years old from seed with site indices from 63 to 80.

Both stands were established on areas denuded by the 1910 fire. The area now occupied by the 36-year-old stand was reburned in 1919 and planted in 1924. Because of the double burn, the stand is nearly pure planted white pine. By contrast the 43-year-old plantation, which was not preceded by a second burn, contains a small component of naturally seeded Engelmann spruce, lodgepole pine, western larch, and alpine fir.

At their present ages, these plots average 27 percent more volume and 21 percent more basal area than normal second-growth stands having the same site indices. This greater cubic-foot and basal area production has been put on 38 percent fewer stems than are indicated for equivalent normal stands. The mean stand diameter of the plantation is 6.3 inches, compared to a normal of 4.4 inches, or a difference of 1.9 inches. When only the dominant and co-dominant stand is considered, the difference is 0.6 inch.

Apparently, as a result of uniform wide initial spacing of trees, the plantations have gotten off to a faster start than fully stocked natural stands. How long these stands can maintain their high initial growth rates may depend on opportunities for early thinning.

Plantations of western white pine have three advantages over natural stands: they can be started promptly without depending on occurrence of good seed years; they have a high initial growth rate that further augments their prompt start; and they have a high proportion of the most valuable species.

GENETICS

Breeding Blister Rust-Resistant Western White Pine of Good Growth and Quality

Development of a blister rust-resistant western white pine is a joint project between Blister Rust Control, Region 1 of the Forest Service, and Intermountain station. Rust resistance aspects are the responsibility of Blister Rust Control. Major accomplishments in the vigor-quality phases, which are a part of the station's research program, are described below.

1. As mentioned in previous reports (1955 and 1956) a series of tests designed to stimulate flowering in western white pine has been started. Most of these have been successfully established, and we can look forward to

information that will be valuable for use in seed orchard establishment within a few years. One of the tests, that of applying cultural treatments to young trees, has already begun to show results. In this test 6-year-old trees were planted in the fall of 1955. The cultural treatments including watering, cultivating, and fertilizing (a 14:14:14 mixture of commercial fertilizers) are being applied yearly, both singly and in all possible combinations. Second-year height growth as measured in the fall of 1957 is tabulated below. The data are averages of 4 to 8 trees for each treatment.

Treatment	Height growth during 1957 Feet
None	0.19
W (Watered)	.26
C (Cultivated)	.33
F (Fertilized)	.38
WC	.40
WF	.60
CF	.57
WCF	.53

An over-all analysis of variance of the data showed significance at the 5-percent level. The trees given any kind of treatment grew faster than the controls, and the apparent effect of fertilizing was greater than either of the other single treatments. However, the greatest response was obtained when fertilizing was coupled with either watering or cultivating or both. The average growth rate of trees receiving either of those three combinations (WF, CF, or WCF) was about three times as great as that of the controls. Apparently the effects of fertilizing were largely additive to either or both of the other two treatments. Watering and cultivating, on the other hand, showed only a slight additive response when used together without fertilizer and none at all when used together with fertilizer. Apparently the main benefit of cultivating resulted from reduction in competition with other vegetation for available moisture. If that is true, the response may change in an unusually dry season, and watering may show greater effect. However, cultivating appeared to improve the general vigor of plants, especially in the presence of fertilizer. Fertilizing caused heavy weed competition, but without cultivation the fertilized trees often appeared to have smaller and less vigorous crowns than trees both fertilized and cultivated.

The particular cultural treatment best suited to stimulate vegetative growth may not be the best for stimulating early and abundant flowering. Some early information on this point may soon be obtained from another test already established in which the full cultural treatment described above is being applied to trees 10 to 15 years old. Further tests, in which the fertilizer mixture will be varied, are planned.

2. A preliminary experiment in selective fertilization conducted during the years 1954-56 has led to the tentative conclusion that western white pine trees are largely cross-pollinated under natural stand conditions. The importance of this subject stems from the fact that the potentiality for selfing in seed orchards, where clones or closely related trees are used, may be magnified and that selfing usually results in inbreeding depression. The preliminary experiment was concerned with the relative ability of a self-fertile tree to produce germinable selfed seed when its pollen must compete with that of another tree.

In the spring of 1957 this work was extended in an attempt to determine the nature and extent of selfing that may be expected under seed orchard conditions which entails several different facets. Pollinations made for these new tests were apparently successful, but of course several more years will be required for completion. A report covering the earlier work has been submitted for publication in Silvae Genetica.

3. During 1957 a technique for evaluating tree competition around western white pine selections was tried. The method was merely an application of the variable plot-radius cruising technique, using a wedge prism having a basal area factor of 10.[4/] The method was applied to a total of 153 selections (25- to 60-year-old dominants and codominants) situated in stands of varying density The selection was the center of the "plot" and all other live or recently dead trees whose stems overlapped when viewed through the prism were counted. The count of trees thus obtained was then converted to basal area and used as a measure of competition.

This method was found to be fast and generally satisfactory. The competition data, along with other measurements previously obtained, were used in an analysis to determine effects of competition. Results showed that although increasing competition significantly increased total height, decreased d.b.h., and decreased stem volume, last 10-year periodic annual height growth was not significantly affected. The apparent effect on total height was explained on the basis of more intensive nongenetic selection for early growth rate in dense as compared to open stands. The findings support previous beliefs that last 10-year periodic annual growth is superior to mean annual growth for use in tree selection work in young western white pines.

Racial Variation in Ponderosa Pine

Recent examination of a 45-year-old test of racial variation in ponderosa pine showed that only minor changes in performance have occurred during the past 20 years. Progenies from localities nearest the planting site have generally continued to be superior in growth rate and survival to progenies from the more distant localities. This test, begun in 1911, consists of a planting on the Priest River Experimental Forest of seeds from 21 different

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4/ Bruce, David. A new way to look at trees. Jour. Forestry 53: 163-167. 1955.

sources of ponderosa pine, representing most of the range of this species. A report in 1937[5/] proved the existence of races in this species and cautioned against the use of seed from outside of the North Plateau region (generally eastern Washington and Oregon, northern Idaho, and western Montana) for use in planting in northern Idaho.

The ten progenies within the North Plateau region now average 37 percent greater in total height (using the tallest one-third of the trees in each progeny) than progenies from regions to the east and south. The single surviving progeny from the North Pacific region (Siskiyou) has grown fully as well as or better than progenies from local sources. However, survival of trees from that progeny has been very poor. A severe frost in 1924 killed most of the Siskiyou trees and all of those from the other North Pacific progeny, namely Shasta.

The most recent data from this test are being analyzed in detail to study the relationship of growth performance at the planting site to climatic factors of the source locality. The Pacific Northwest station has conducted a similar study of this species in their region, and it is planned to coordinate recent data from the two studies and to report jointly when completed.

Field Tests of Ponderosa Pine Hybrids

For several years this station has been field-testing pine hybrids developed by the California Forest and Range Experiment Station. In all of these crosses both the seed parents and the pollen parents were not native to Montana. In one series, ponderosa pines from a California source were crossed with pollen parents of the *scopulorum* variety of the pine from Colorado, and the progeny were planted in two localities in Montana. Along with these hybrids several lots of wind-pollinated ponderosa pine from California and two wind-pollinated lots from Montana were planted as controls. A single lot of hybrids between ponderosa pine from California and pollen parents of Apache pine (*Pinus engelmanii*) was also planted.

Five years after outplanting, none of the nonnative control trees and the Apache pine hybrids survived. Mortality was also extremely high among all other lots planted on the eastern Montana site, where only 5½ percent of the trees survived. Losses at this site resulted mainly from drought.

Average total heights of the surviving hybrid and native control lots in the western Montana plantation are shown in the following tabulation. The comparison shows little difference in average diameter between hybrids and controls. All the hybrids are shorter than the controls and are slightly narrower crowned. Note that both control lots are considerably taller than the hybrids. Because of the extremely low survival, the eastern Montana plantation has been abandoned. The western Montana test will be continued however.

5/ Weidman, R. H. Evidences of racial influence in a 25-year test of ponderosa pine. Jour. Agr. Res. 59: 855-887. 1937.

Seed parent		Pollen parent	Av. total height Feet
P. ponderosa (Eldorado 2,800 ft. elev.)	x	P. ponderosa v. scopulorum (Colorado)	0.61
P. ponderosa (Eldorado 4,000 ft. elev.)	x	P. ponderosa v. scopulorum (Colorado)	.66
P. ponderosa (Eldorado 5,400 ft. elev.)	x	P. ponderosa v. scopulorum (Colorado)	.84
P. ponderosa v. scopulorum (Helena)	x	wind	1.04
P. ponderosa (Kootenai)	x	wind	1.16

FOREST DISEASE RESEARCH

Forest Disease Research attained division status at the Intermountain station in 1957, when a division chief was added to the staff in September. During the year the station's soil scientist, who had been studying pole blight of western white pine, transferred from the disease research staff to the Division of Watershed Management Research in Ogden.

The division's accomplishments and activities during the year include: the definite confirmation of a former lead to the cause of pole blight; the determination that permanent long-period weather stations will aid in predicting the success of white pine blister rust control operations on surrounding control units; dispersal of the pine-infecting spores of blister rust was simulated by means of silver iodide particles; mortality of ponderosa pine from the Elytroderma needle blight was summarized for a 7-year period on study plots in southern Idaho; experimental results to date on control of dwarfmistletoe by chemical sprays were summarized; dwarfmistletoe surveys were completed on two more national forests; *Poria weirii* was found to be causing considerable tree mortality in the Inland Empire; and the forest disease staff produced 10 technical publications in 1957.

POLE BLIGHT OF WESTERN WHITE PINE

A previous lead to the cause of pole blight was strengthened in the past year's research on this disease. The 1957 results strongly indicate that pole blight is a physiological disease brought on by moisture deficiency in the soil. Soils on 353 plots have been studied since 1954, and no stands affected with pole blight have yet been found on soils having more than 5 inches of available moisture storage capacity in the upper 3 feet of soil, but the disease occurs commonly on soils having only 0.7 to 5.0 inches.

Soil Survey

An extensive soil survey of 61 white pine pole stands, 50 to 90 years old, located throughout the western white pine type in western Montana, northern Idaho, and eastern Washington was carried out to determine whether any stands affected by pole blight were growing on deep soils (available for root growth and penetration for 36 inches or more) with high available moisture storage capacities (more than 5 inches in 3 feet of soil). Data were collected on 319 plots located in these stands. While many of the data must still be analyzed, present conclusions are that much greater opportunity is provided for uniform root growth and distribution in healthy plots, particularly those in healthy areas. Even though both uniform root growth and greater available moisture storage capacity are probably highly significant in determining the health of a stand, adequate moisture distribution and availability from sources other than direct precipitation are also important. Soil moisture recharge is much more limited by shallow soils in diseased stands than in healthy stands in either diseased or healthy areas.

Artificially Imposed Drought Experiment Extended to the Clearwater Area

Another plot was established to determine the effects of artificially imposed drought on growth. A plastic covering, similar to one used and reported in 1956, was installed on a plot located in a 60-year-old white pine stand in the Clearwater area. This area lies outside the present boundary of pole blight infection. The purpose is to study the effect of moisture stress on white pine root growth and mortality.

Effects of an artificially imposed moisture stress on white pine are being determined as part of the pole blight research program. A shelter, tree caps, and perimeter trench aid in intercepting rainfall and soil drying.

WHITE PINE BLISTER RUST MICROCLIMATE

Whether an area constitutes a high hazard to the success of control measures applied to blister rust depends largely upon the microclimate on that particular area. Where the microclimate is exceptionally favorable for rust development and spread, control of the rust is impossible by standard procedures. The ultimate objective of microclimate studies now being made is to define these high hazard areas, make them readily recognizable, and to locate and delineate them.

Use of Permanent Long-Period Weather Stations

To apply the weather records of long-established stations to surrounding study areas it is necessary to be able to correlate those records with microclimate measurements on the study areas. To apply the chances for rust development determined for long period stations to nearby areas, information is needed on variation of moisture and temperature as topography and vegetative cover change. To provide this information, the exploratory study of variation in summer temperature and humidity made during 1956 was extended to include additional classes of vegetative cover, position with regard to terrain, direction of exposure, and elevation. Observations were made at 219 stations on four different types of areas in the Kaniksu National Forest. Temperatures and humidity at the various stations are being compared with those at control stations located in the open on level terrain. Differences are consistent enough in most areas to indicate that a few weeks of observation are sufficient to establish reliable comparisons between various sites and nearby long period weather stations.

Fifty-nine pairs of the stations were established under like vegetative and topographic conditions to determine the variation in temperature and moisture between similar sites. Considerable variation, particularly in maximum temperature, was observed between pairs of stations on the similar sites. Greatest variation was on upper slopes of knolls. Differences in maximum temperatures between stations on three knolls having the same elevation, aspect, slope, and vegetation ranged from -7^{o} to $+14^{o}$ F. On localities where such variation is likely, additional temperature observations may be needed in each working unit to determine relationships of temperature and humidity to long period stations and from these relationships chances for rust on the site. On localities where variation is not expected to be excessive, chances for rust determined for the long period stations can be extended directly to the site from a knowledge of its terrain and vegetative class.

The mobile atmospheric research laboratory of the Forest Fire Laboratory in Missoula integrated the observations at the fixed stations established in the upper Kalispell Creek area.

Simulated Spore Dispersion

The Forest Fire Laboratory cooperated in an attempt to simulate spore dispersion by means of silver iodide particles in the upper Kalispell Creek area. Upper Nuisance Creek, a fork of this drainage, located just south of a low pass on a ridge connecting Diamond Peak and Kalispell Rock, is a blister rust problem area. The central question to be answered is: Are blister rust spores released from ribes on the northwest slope of Diamond Peak (outside of the control area) carried through the pass into the upper Nuisance Creek area where they infect pines? Petit Lake, at the north end of the pass, is considered to be a possible source of moisture. When the lake is warmer than the air, convective currents over the lake provide a means of carrying spores, brought down the slope of Diamond Peak by drainage winds, to higher levels. If air flow from the north prevails aloft, the spores might be carried through the pass into the Nuisance Creek area.

A silver iodide generator was operated on the northwest slope of Diamond Peak on a clear cold night favorable for the proper drainage winds, convective currents, and the northerly flow described above. The plume of silver iodide particles was soon detected in the pass by means of a cold chamber and later was detected in upper Nuisance Creek. This brief experiment indicated that particles can be carried through the pass as hypothesized. Further study will be made under conditions favorable for spore dispersion in this area. The experiment also demonstrated the usefulness of silver iodide particles as a means of determining spore distribution patterns from a known source when actual spores are difficult to trap or identify, are few in number, or are released from so many sources in the area being studied that origin of those trapped would be doubtful. Further comparison will be made of the relative size and rate of fall of silver iodide and white pine blister rust spores to determine the applicability of results obtained from a study of silver iodide dispersion to a spore dispersion problem.

PONDEROSA PINE BLIGHT

The *Elytroderma deformans* leaf and twig disease of ponderosa pine, although widely spread throughout the station's territory, continues to remain epidemic only on localized areas where it has been severe for several years. Data obtained in 1957 showed but very little decline in intensity of the disease from that recorded in 1956. Intensity of the blight epidemic, however, is now far below the peak of 1950 and 1951.

Damage Studies

Studies were started in the Intermountain region in 1951 on six plots established in blighted stands, and data have been taken annually on them. The main purpose of these studies is to determine the rate of mortality and extent of volume loss from the blight as a basis for planning salvage logging in affected stands. The mortality that has occurred to date on the plots is summarized in table 3.

Table 3.--Seven-year loss through mortality from Elytroderma needle blight, by stand types, on sample plots in affected ponderosa pine stands on the Boise National Forest, 1951 to 1957, inclusive

Stand description	Basis			Mortality			
	Plots	Trees	Volume	Trees		Volume	
	Number	Number	Board feet 1/	Number	Percent	Board feet 1/	Percent
Virgin, mature	3	76	72,140	12	15.8	5,890	8.2
Mature, cutover	2	57	53,370	6	10.5	2,970	5.6
Second growth, immature	1	28	19,110	7	25.0	3,380	17.7
All stands	6	161	144,620	25	15.5	12,240	8.5

1/ Scribner Decimal C scale.

All ponderosa pines on all plots were infected. Infection occurred sometime prior to plot establishment in 1951. To date 15.5 percent of the total 161 trees originally on the plots have died; however, the volume loss is only 8.5 percent. Therefore, mortality has occurred in the smaller size classes. Mortality in second growth has been about nearly 3 times that in mature or cutover stands.

Twenty-three of the 25 pines that succumbed were in Keen classes 2C, 2D, 3C, or 3D. No mortality has occurred in class A trees. Increment of these pines had been greatly reduced for 15 to 40 years prior to their death. There thus appears to be a relationship between tree vigor or condition and mortality. Further evidence of this relationship is indicated by the fact that all mortality has occurred in trees originally classed as fair, poor, or very poor--most of it in the latter two classes. Death has come slowly, and some trees originally recorded in those classes are still alive. Trees in poor condition never seem to improve noticeably, whereas trees in good or excellent condition when plots were established are not as heavily infected now as they were in 1951. Salvage logging of severely diseased trees is therefore suggested as a means of reducing losses in affected stands.

Information on seedlings and saplings has been obtained from a separate plot established in 1951 within a severely blighted stand of mature ponderosa pine. The plot contained 80 trees, 25 of which were infected. They ranged from 8 to 21 feet in height, but the 55 uninfected trees ranged from 0.6 to 5.1 feet. Between 1951 and 1957, inclusive, 10 of the infected trees (height range 9 to 20 feet) died. All of these except one were either damaged by porcupines, suffered snow bending, or both. Since 1951 only two additional trees have become infected. Both are badly suppressed individuals about 1.5 feet in height and between 12 and 15 years old. The remaining uninfected trees are all vigorous and have maintained a good annual growth rate.

EXPERIMENTS IN CHEMICAL CONTROL OF DWARFMISTLETOE

The dwarfmistletoes Arceuthobium spp. occur in most coniferous species throughout the station's territory and are the most damaging pathogen in some of them. Reduction of losses caused by these parasitic plants presents the most important pathological problem in silvicultural management of young stands.

Direct control by use of chemicals particularly appeals to many forest managers because they believe it would simplify control measures. Chemical control experiments have been undertaken at several western stations in the United States and at Canadian Laboratories, and many chemicals have been tried on several species of dwarfmistletoe involving various species of host trees.

Control Experiments in Lodgepole Pine Dwarfmistletoe

Experiments on chemical control of the lodgepole pine dwarfmistletoe *Arceuthobium americanum*, started in the Intermountain region in 1952, have been continued through 1957. These have been so-called screening tests conducted on plots about one rod square in lodgepole pine reproduction to determine whether any of the test materials would be toxic to the parasite without seriously injuring the pine host.

A total of 17 different materials, mainly so-called herbicides, has been used. Also mixtures of two or more materials were tried, and oil in small amount was added to some solutions. These materials were sprayed on both the dwarfmistletoe plants and the pine foliage by 3- to 5-gallon capacity pressure-type sprayers.

To date 127 separate tests have been conducted on the same number of plots. No material yet tested, or combinations of materials, has given a satisfactory kill of both the aerial portions and the endophytic or so-called root system of the dwarfmistletoe plant. Several materials killed the aerial portions, but resprouting from the endophytic portion occurred in time. Three materials retarded resprouting for a maximum of 2 years following application.

Spraying has been conducted in spring, summer, and early fall. Apparently the stage of vegetative activity of the dwarfmistletoe plant is important in timing the spraying. Spring spraying, when seasonal growth of the plant is just starting, has been less effective on aerial portions of the parasite than summer spraying, when growth activity was greater. A much poorer kill of the aerial portion of the dwarfmistletoe was obtained when soil moisture was low than when it was high.

Oil emulsions were consistently toxic to the host; the oil not only burned pine foliage, but killed some small trees.

Only two materials have been tested on *Arceuthobium douglasii*, the dwarfmistletoe in Douglas-fir. Neither of these gave a satisfactory kill.

FOREST DISEASE SURVEY

A small allotment is available for disease surveys in Region 1, but no money has been available for similar surveys in Region 4, where such surveys are urgently needed.

Survey of pole blight occurrence was continued in Region 1, but highest priority in disease surveys there is for detection and appraisal surveys of the dwarfmistletoes. Distribution, intensity, and damage appraisals of dwarfmistletoes were started in the Inland Empire in 1956. Each national forest was designated as an area unit, and its ranger districts as subunits for this survey.

Dwarfmistletoes

Distribution and damage appraisal surveys of the dwarfmistletoes were continued in 1957. Roadside reconnaissance has now been made in four national forests in the Inland Empire and a sample strip survey with randomized plots in two of these forests.

On all four forests combined, the status of dwarfmistletoe was recorded along 2,046 miles of roadside strip, using one-tenth mile as the basic unit for determining occurrence and abundance. In the plot survey, 600 1/5- and 1/10- acre plots were established in merchantable stands of Douglas-fir and larch in the Colville and Nezperce Forests. Results of these surveys are shown in table 4.

Table 4.--Incidence of dwarfmistletoe recorded from roadside and plot surveys by species in four national forests in the Inland Empire

National forest	Roadside survey 1/				Plot survey 2/	
	Douglas-fir	Western larch	Lodgepole pine	All species	Douglas-fir	Western larch
	Percent					
Colville	76	86	25	77	80	92
Nezperce 3/	62	79	53	70	78	92
Coeur d'Alene	--	64	--	--	--	--
Kootenai	--	70	--	--	--	--

1/ Based on distance traveled through infested areas, expressed as a percentage of the total distance traveled, by species.
2/ Based on the infected board-foot volume (Scribner), expressed as a percentage of the total board-foot volume, by species.
3/ Only the west half of the Nezperce Forest was surveyed.

The roadside survey showed no great difference in abundance of larch dwarfmistletoe in the overstory of mature stands, cutover stands, or stands of fire residuals. However, incidence of Douglas-fir dwarfmistletoe appears to be greater in cutover stands than in other stand types containing merchantable overstory trees. Dwarfmistletoe was 2.4 to 7.1 times as abundant in pole-sized stands occurring as an understory than in pole-sized stands having no overstory. Infection in western larch stands in the Coeur d'Alene and Kootenai Forests was not correlated with composition of larch; dwarfmistletoe was as common in stands having low larch composition as in stands having a moderate or high percentage.

More than one million board feet of merchantable-sized Douglas-fir and western larch were contained in the 600 plots on the Colville and Nezperce Forests. Trees containing 83 percent of this volume were infected--79 percent of the Douglas-fir volume and 92 percent of the larch volume. Trees recently killed by the dwarfmistletoes contained 7 percent of the total Douglas-fir volume and 13 percent of the total larch volume. This does not

represent the total dead volume--only that in which dwarfmistletoe was considered to be a major factor contributing to death. In the nonmerchantable stand on the plots, 44 percent of the Douglas-fir stems in the understory and 61 percent of the larch stems in the understory were infected with dwarfmistletoe

Some forest managers know the destructiveness of dwarfmistletoe, but many are only convinced of its seriousness and take action to cope with the disease when overwhelming evidence of its damaging effect is presented. The results of dwarfmistletoe surveys to date have supplied information that points out the magnitude of the dwarfmistletoe problem.

Mature Douglas-fir stand on the Colville National Forest showing trees with entire crowns broomed from heavy dwarfmistletoe infection.

Poria weirii

The root disease Poria weirii, heretofore considered an important root pathogen of Douglas-fir only on the Pacific Coast, has been found to cause considerable mortality in the Rocky Mountain type Douglas-fir and several associated tree species on the Coeur d'Alene National Forest and in several centers of infection on other national forests within the Inland Empire. A survey to determine the extent and magnitude of losses from this disease should be made.

FOREST INSECT RESEARCH

During 1957 the three-phase program of research, insect surveys, and technical assistance on control projects carried on at the station progressed satisfactorily.

Major emphasis in research was placed on studies of spruce budworm and Douglas-fir beetle with additional limited work on Black Hills beetle, spruce mealybug, larch insects, white fir needle miner, black pine leaf scale, the risk-rating and selective logging of ponderosa pine as a means of indirect control of western pine beetle, and improvement of insect survey techniques.

Insect populations remained at a fairly high level and imposed a heavy workload for station entomologists. Large-scale control projects against spruce budworm and bark beetles required technical assistance during the planning stages and execution of control in the field.

It is not intended to present details of all of the research of the division program in this report. Items have been selected from the three major fields of activity to illustrate the progress made during 1957.

RESEARCH

Douglas-fir Beetle

Studies of the Douglas-fir beetle, *Dendroctonus pseudotsugae* Hopk., started in 1956 in southern Idaho were continued through 1957. Attention was given to population sampling and the cataloguing of natural control organisms and assessing their abundance and effect.

Accurate estimates of populations are essential to the program, but sampling of standing trees poses a problem of mechanics and manpower when large numbers of samples are required. Last year it was determined that samples midway of the infested length of the bole gave more satisfactory results than those at the extreme lower and upper ends. Further study indicated a broad middle zone in which equally good results were obtainable. The lower limit of this zone was between 9 and 12 feet from the ground. Application of this finding obviates the need to fell trees or climb to excessive heights for sampling.

Knowledge of brood survival is important in determining trends in populations. Brood survival was measured with good results by rearing infested slabs (p.27). Slabs have several advantages over other methods: (1) grouping of material in one location permits daily observation and collection of insects emerged from slabs, (2) larger numbers of samples can be handled than by attaching cages to trees or logs, (3) mites attached to emerged beetles can be recovered for study, and (4) cages containing slabs can be protected from damage that may befall screen field cages.

Accurate determination of egg density is essential for reliable estimates of initial beetle populations as a base for determining relative survival and mortality at intervals during maturation of the brood. Measurements of 274 egg galleries averaged 7.93 eggs per inch. Number of eggs and gallery length had a straight line relationship.

Observations of biological factors that effect reduction in beetle populations have produced interesting and significant facts:

1. Mites are found in staggering numbers on emerged Douglas-fir beetles; two beetles each had 238 immature mites clinging to them, and on 750 beetles a total of 20,000 mites was recorded. While these mites may not affect the life of the adult beetle, the transport of the mites by the adult beetles aids in their distribution. Evidence points to mites as important predators of beetle eggs.

2. The seasonal history of Enoclerus sphegeus, a predator on Douglas-fir beetle, proved to be different from that reported from studies of other Dendroctonus species.

3. Observations of low-level infestations in southern Idaho where previous populations had been at epidemic level and very active infestations in southern Utah provided interesting contrasts. In Utah, infested bark contained more brood and relatively fewer predators. A parasite abundant in Idaho was almost absent in southern Utah.

Tree climbing to obtain samples of the Douglas-fir bark beetle. This method enabled the sampling of optimum stem locations without the need for falling the trees.

Through continued study of the interrelationships of the beetle, its natural enemies, and its environment, the division plans to determine factors responsible for variations in populations and tree-killing. Such knowledge may lead to the development of methods of lessening damage to extensive Douglas-fir forests.

Spruce Budworm

Phases of research on spruce budworm are divided between the Missoula laboratory and the Boise Research Center. At Boise the main effort is on studies of populations and subsequent damage; at Missoula the primary objective is to determine biological factors affecting populations.

During 1957, the first year of research at Boise on populations and damage, the prime consideration was development of sampling techniques for collections of budworm at various developmental stages during the seasonal history of the host.

Bole samples from infested trees produced second instar larvae under laboratory conditions early in the winter after temperature conditioning. Field-collected material stored out of doors for several months was subjected to -25° F. for varying periods of time prior to rearing tests. Similar lots were subjected to 40° F. in a similar manner. The best results were obtained by subjecting bole sections to a temperature of -25° F. for 8 hours. More critical work involving three temperature treatments

Slabs containing Douglas-fir beetle brood were obtained in the fall with a power saw for convenient rearing of overwintering adults.

and a greater range of times of exposure is under way at Missoula. This study utilizes bole samples and artificial hibernating sites of gauze. Percentages of recovery can be determined from the artificial hibernaculae. The advantage of forcing hibernating larvae from their hibernaculae out of season lies in the resulting ability to estimate populations expected in the spring well before normal emergence. The results bear directly on planned control projects and upon studies of populations.

Analysis of samples taken from 15-inch twigs clipped at three levels within the crowns of Douglas-fir trees showed that midcrown sampling furnishes reliable estimates. Sampling of larval instars from early spring until pupation at four periods showed no significant difference between the first three collections; but there was significant difference between these three and the fourth. Therefore, in sampling budworm larvae two population standards should be used: one for early instars and one for mature larvae.

Studies of the bionomics of the spruce budworm in Montana were continued during 1957 with the addition of study plots in three areas where collections made throughout the season are examined for evidence of biological factors that effect reduction of populations. Similar data were taken during studies in southern Idaho.

Glypta fumiferanae continues as the most effective parasite in Montana. This species, with a less numerous associate, Apanteles fumiferanae, parasitizes the tiny overwintering larvae and kills them when they are half grown. Parasitism of overwintering larvae averaged 36 percent during 1957. Data from collections of larger larvae and pupae have not been completely analyzed but indications are that there have been no striking changes in parasitism since last year.

Egg mass surveys were made in four study plots for the first time in 1957. Collections were made well after all eggs had hatched because hatched masses are more easily detected than unhatched ones. The task is time-consuming and difficult, and a routine check revealed that many masses had been overlooked on first examination. Comparison between numbers of eggs on terminal 15-inch twigs and on whole limbs measured in 15-inch equivalents revealed about three times as many egg masses per unit on an entire limb basis.

The data taken in study plots will reveal the trend in biological factors in various areas of the extensive outbreak of budworm and will determine their effectiveness in regulating changes in populations.

Fir Needle Miner

Epidemics of the white fir needle miner, Epinotia meritana Hein., in Bryce Canyon National Park and the adjoining Dixie National Forest in Utah have caused serious defoliation during the past 20 years. As a result,

mortality of limbs, tops, and some entire trees has occurred. The present epidemic started about 1949 and increased in severity until this year. Considerable tree mortality has developed--more in fact than had previously been experienced.

In 1955 studies were started to collect biological information that might aid in developing possible methods of control. These studies indicated that biological control organisms were present during 1955 at an ineffective level of 8 percent. In 1956 the parasitism increased to 36 percent, and in 1957 reached the level of 71 percent; certain limited areas showed 96 percent. The parasites appeared to be significant factors in reducing the populations to endemic level.

Previous tests of DDT to control the white fir needle miner were not successful; so an experimental aerial spray test using malathion in oil was undertaken against the larval stages. Mortality averaged 75 percent, but it is believed that earlier application of spray would have given better results.

With the reduction in populations during 1957 it is believed that the present outbreak has run its course. The limited research has accumulated facts on life history, seasonal history, and parasites that will be valuable in studies of any future outbreaks.

Tree Class Based Upon Susceptibility to Pine Beetles

A study is under way in Montana and northern Idaho to test the validity of the risk rating of ponderosa pine on susceptibility to attacks by western pine beetle, *Dendroctonus brevicomis*, and other pine beetles. This risk-rating system, developed in California, is based on current tree vigor as judged by visual crown characteristics; trees having poor vigor are more susceptible to attack than stronger trees.

In Montana this process of risk rating is made difficult because the mountain pine beetle is also a primary pest of mature ponderosa pine. Preference of this beetle for high-risk trees over others is open to question. In order to determine the attack patterns in the same trees by different scolytid species, particularly western pine beetle and mountain pine beetle, data have been gathered from different areas.

The infestation patterns on the boles of 29 ponderosa pine trees infested and felled in 1951, 53 trees in 1954, and 84 trees in 1956 were analyzed during 1957. Interesting data were developed. The trees were scattered in typical mature ponderosa pine stands at locations reaching from western Montana eastward across the Continental Divide into southeastern Montana and northwestern South Dakota. Trees east of the divide were the characteristic 2-needle Rocky Mountain form of ponderosa pine (*var. scopulorum*).

The infestation patterns confirmed meager earlier pattern analyses showing that the primary attacks were made by the western pine beetle in the westernmost stands in Montana. Progressively eastward toward the Continental Divide, attacks by this beetle became less dominant. They were replaced almost entirely along the western slopes of the divide by the tree-killing attacks of the mountain pine beetle. Since no attacks of the western pine beetle were found east of the divide, we believe that the western pine beetle is not a pest of the scopulorum variety of ponderosa. Here, instead, the attacks were made by the mountain pine beetle or the Black Hills beetle, D. ponderosae Hopk. These two beetle are indistinguishable, either morphologically or by the type of egg and larval gallery design; consequently many insect taxonomists believe that the two species are identical.

The 84 trees felled in 1956 showed considerable variation in infestation pattern in the four geographic areas sampled.6/ The schematic presentation in figure 2 indicates the following:

1. The predominance of western pine beetle attacks in Area 1.

2. The predominance of mountain pine beetle and/or Black Hills beetle attacks in the remaining areas.

3. The apparent wide distribution and comparative abundance of ips engraver beetles.

4. The comparative average size of ponderosa pine trees on each side of the Continental Divide.

5. The consistency (91 percent) of basal bole examinations to identify correctly the beetle species responsible for the death of the tree.

Many of the field data and the analyses of them used in this study during 1957 were gathered and studied cooperatively with the Montana State University School of Forestry. The data were used as part of a thesis submitted by a graduate student in partial fulfillment of requirements for the degree of Master of Science in Forestry granted in June 1957.

6/ Area 1, westernmost part of Montana, west of the Whitefish,Hungry Horse, Mission, and Sapphire Ranges; Area II, between these ranges and the Continental Divide; Area III east of the divide and north of the Yellowstone River in Montana; and Area IV, south and east of the Yellowstone River in southeastern Montana and northwestern South Dakota.

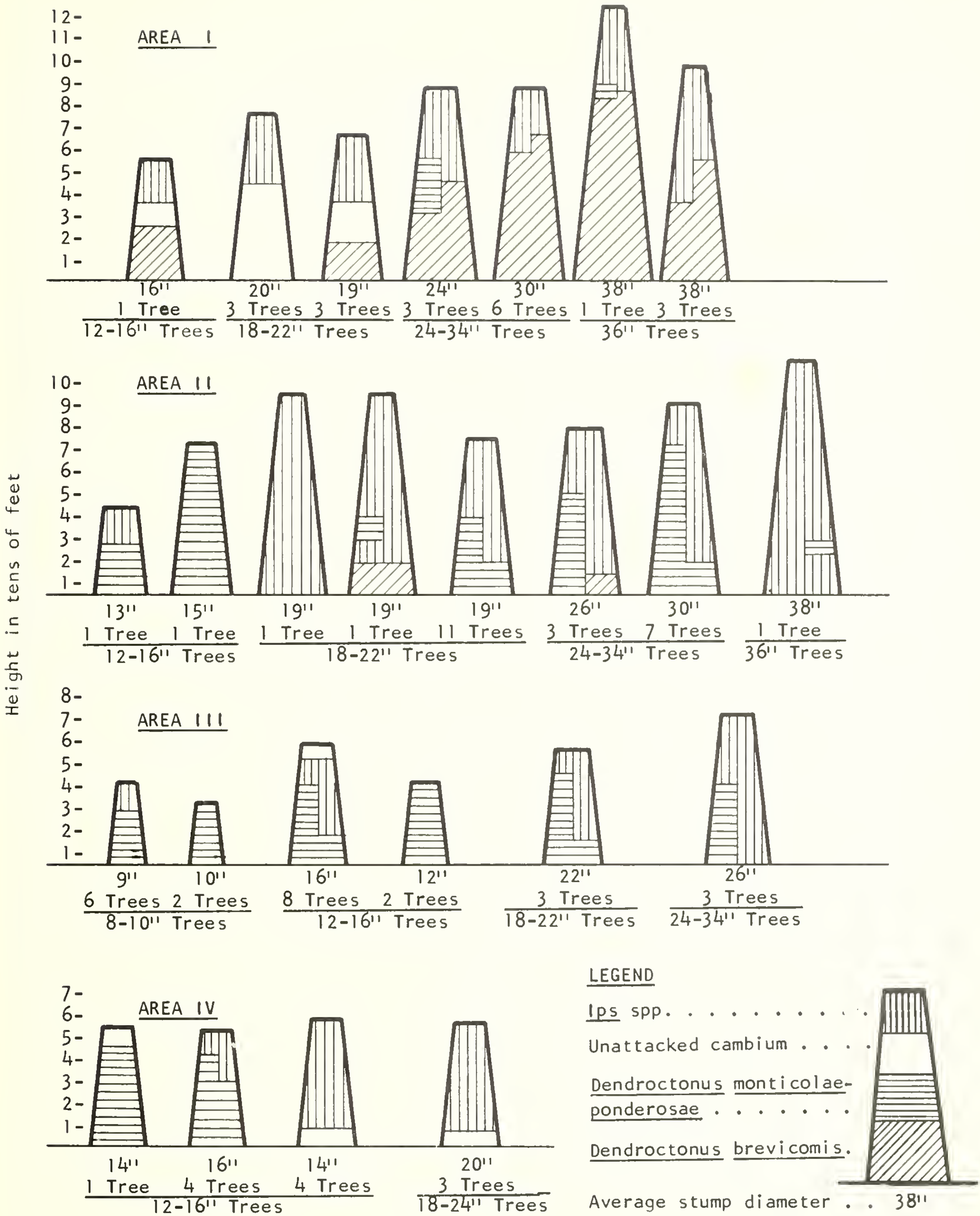


Figure 2.--Bole infestation patterns of scolytid beetles on trees sampled in study areas I to IV in the year 1956

Improvement of Survey Methods

Improvement of appraisal surveys is a continuing need. Attempts are being made to describe the elements considered in interpreting field observations so that appraisal data can be recorded more accurately. Tests were made in two infestations in Montana during 1957 to assess the importance of four characteristics in determining the trend of populations of mountain pine beetle. The four characteristics are: (1) size of trees infested in relation to sizes of uninfested trees; (2) density and condition of brood under bark; (3) percentage of the tree circumference infested, and (4) whether trees occur singly or in groups. If the larger trees in a stand are infested, if they contain heavy healthy brood for the entire or greater part of the circumference of the tree, and if these infested trees occur in groups, an upward trend or continuing high level infestation is indicated.

Determining the success of aerial spray projects for control of the spruce budworm, *Choristoneura fumiferana* (Clem.), requires extensive sampling. Sampling, conducted prior to and after the application of the spray, is designed to evaluate the effect of the spray in reducing the budworm larval population. Limitations of time and manpower govern the extent of coverage in sampling.

Research on sequential sampling of populations of budworm larvae indicated that its application during control operations would effect more satisfactory measurements. The sequential plan, while having no fixed sample size, permits the classification of pre- and postcontrol populations within the predetermined limits of accuracy. Certain basic knowledge is required to develop a sequential plan for sampling budworm larval populations. It is necessary to determine the type of frequency distribution since this governs which formula will be used. Sufficient information must be known of the number of insects per sampling unit to set class limits or degrees of infestations. In this test, class limits were determined by general correlation between the average number of larvae and percent defoliation per twig as found during a budworm population-damage study. Ordinarily in determining the success of spray projects arbitrary definitions have been devised for setting four classes of control: excellent, good, marginal, and poor. For purposes of this test of sequential sampling only two categories were established: satisfactory--reduction in population 95 percent and above; and unsatisfactory--a reduction of less than 95 percent.

Prior to the use of sequential sampling, fixed collection lines and plots were established in as many spray blocks as was possible, and collections were made in each plot at 5-chain intervals along each established 50-chain line. In the majority of spray operations to date only one such mortality line could be run in a particular spray block of 3,000 to 8,000 acres. Consequently the mortality estimate obtained has been based entirely on one figure not based on a predetermined confidence level.

In contrast, by use of sequential graphs for precontrol and postcontrol sampling of larval populations it is possible to increase the percent of spray blocks sampled with little or no increase in numbers of personnel. For example, assuming that collections at three or four of the plots on a line determine the class of infestation during precontrol sampling or the degree of reduction in postcontrol sampling, the operator can offset repeating his procedure on a new line or can increase the number of blocks in which samples are taken. Whether the increase in samples is placed within a single spray block or more spray blocks is governed by the natural variation found within or between blocks.

The following table presents the situation graphically. From 1955 through 1956 the old system was followed, but in 1957 the sequential plan was followed.

Table 5.--Personnel, acreage, and percent sampling in control projects in southern Idaho, 1955-57

Year	Ground personnel	Acreage sprayed	Acres per person	Number mortality lines established	Lines per person	Percent of sprayed blocks sampled
1955	33	893,214	27,067	58	1.45	53
1956	35	475,901	13,597	70	2.00	68
1957	26	660,632	25,409	107	4.12	83

Actually, only a postcontrol sampling will be needed when research into population-damage relationships enables us to interpret the importance of residual populations.

Results of this work are being reviewed for publication.

INSECT SURVEYS

The annual insect detection and appraisal survey program in the Intermountain station territory covered the most important forested areas. The area of 36.9 million acres of commercial forests with additional noncommercial lands of recreational value requires considerable cooperative assistance from other Federal, State, and private land managers in order to accomplish the level of coverage attained. Station entomologists collected and coordinated forest insect information within the area.

Generally speaking, insect outbreaks remain at a fairly high level in the Intermountain and northern Rocky Mountain States. The spruce budworm was again the outstanding forest pest in Montana and Idaho. Larch defoliators in Montana and northern Idaho have been causing considerable defoliation

in western larch stands. Bark beetles are still causing excessive losses in several areas--the Engelmann spruce beetle in Montana and Wyoming, and the Black Hills beetle in Utah. The mountain pine beetle shows distinct tendencies toward increasing populations in parts of Utah, southern Idaho, western Wyoming, and western Nevada. The Douglas-fir beetle is at a relatively low level in most areas but one heavy outbreak has been recorded in southern Utah. Two situations were revealed that are reported in more detail.

The larch casebearer, Coleophora laricella Hbn., was found in western larch forests for the first time in 1957. This European species was first found in the eastern United States in 1886. While it has been known throughout the northeastern United States and Canada and into the Lake States, its presence in western areas has just been recorded.

Approximately 15,000 acres of young western larch were found to be quite heavily infested in the vicinity of St. Maries, Idaho, some 1,700 miles distant from the known infestations in Minnesota. The presence of a new insect of European origin on an area poses questions of means of introduction, what its potential might be on a new host, what natural enemies might be present in the area, and what can be expected of it in the western areas. Only research can furnish the answers.

For the first time since aerial spraying of budworm was undertaken in this country in 1948 and after approximately 8 million forested acres had been sprayed, extensive infestations of spruce mite, Oligonychus ununguis (Jacobi), were found in fir stands of Montana and southern Idaho. The infestations were located in areas that had been sprayed aerially with DDT to control the spruce budworm during 1956, but lesser infestations in southern Idaho also appeared in one area sprayed in 1955.

It is believed that weather during 1956 and 1957 was abnormally favorable for the development of mite populations. Reviews of survey literature reveals that excessive populations of mites were recorded in 1957 over wide areas in the United States on many agricultural crops. This tendency toward increasing populations coupled with the spraying of large areas at the time is believed to have resulted in the extreme conditions that were encountered.

Abnormally heavy mite populations usually subside to more endemic levels in a relatively short time, and fluctuation in populations seems to be associated with weather conditions during the spring months. Abnormally high temperatures coupled with below-normal moisture favor increases.

Assessment of damage resulting from defoliation by the mites remains to be determined. Plans have also been formulated to determine trends of the present outbreak.

Station entomologists have responsibility for furnishing technical assistance in control projects undertaken by land-managing agencies. During 1957 the entomologists participated in precontrol planning; gave advice on methods, materials, and timing of operations; prepared guidelines, assisted in training project personnel; inspected projects as they progressed; and checked results. A total of 10 control projects required technical assistance during the year, involving spruce budworm, fir needle miner, Engelmann spruce beetle, Black Hills beetle, and southwestern pine beetle.

FOREST FIRE RESEARCH

More than 100 million acres of forest and watershed lands in the Intermountain West require protection from fire. Progress in protecting these resources depends heavily upon results of research. During 1957 research progress was made on several major fire problems--lightning fires, fire-danger rating, fire equipment, fire hazard reduction, and fire behavior.

PROJECT SKYFIRE

Project Skyfire is aimed at the critical lightning fire problem in western forests. The principal objectives are: (1) to gain basic information on the occurrence, behavior, and control of lightning fires and on the characteristics of storms that produce these fires; and (2) to develop methods for suppression of lightning fires including study of cloud modification as a possible means of preventing or reducing severity of lightning fires.

Experiments in cloud seeding were emphasized this year. These experiments were performed with assistance of the Munitalp Foundation, Inc., the President's Advisory Committee on Weather Control, U. S. Weather Bureau, Montana State University, Meteorology Research, Inc., California State Division of Forestry, California Forest and Range Experiment Station, National Park Service, and National Forest Administration.

Cloud-Seeding Experiments

Project Skyfire experiments in 1957 concentrated on observation and analysis of effects produced by ground-based, cloud-seeding generators. Targets for these generators were growing cumulus clouds that may be forerunners of lightning storms. Experiments were intended especially to produce large-scale seeding effects within a test area approximately 30 miles long by 15 miles wide.

This test area was located southwest of Missoula, Montana, on the Lolo National Forest (fig. 3). A network of cloud-seeding generators was located near Lolo Pass in the Bitterroot Mountains on the Montana-Idaho border. This network of generators and the associated test area lie near the center of the Skyfire cloud and lightning survey network. Observations and measurements of cloud-seeding results were obtained by a mobile radar unit at West Fork Butte Lookout and by special weather stations. Aircraft flights in the test area and adjacent check areas provided additional information on clouds, temperature, air moisture, nuclei, and other factors. Weather analyses and special forecasting services were provided by the U. S. Weather Bureau Fire-Weather Forecast Center at Missoula. All these stations and the project aircraft were connected by a special radio network.

During the experiments the cloud-seeding generators were operated on 29 days. A summary of these operations follows:

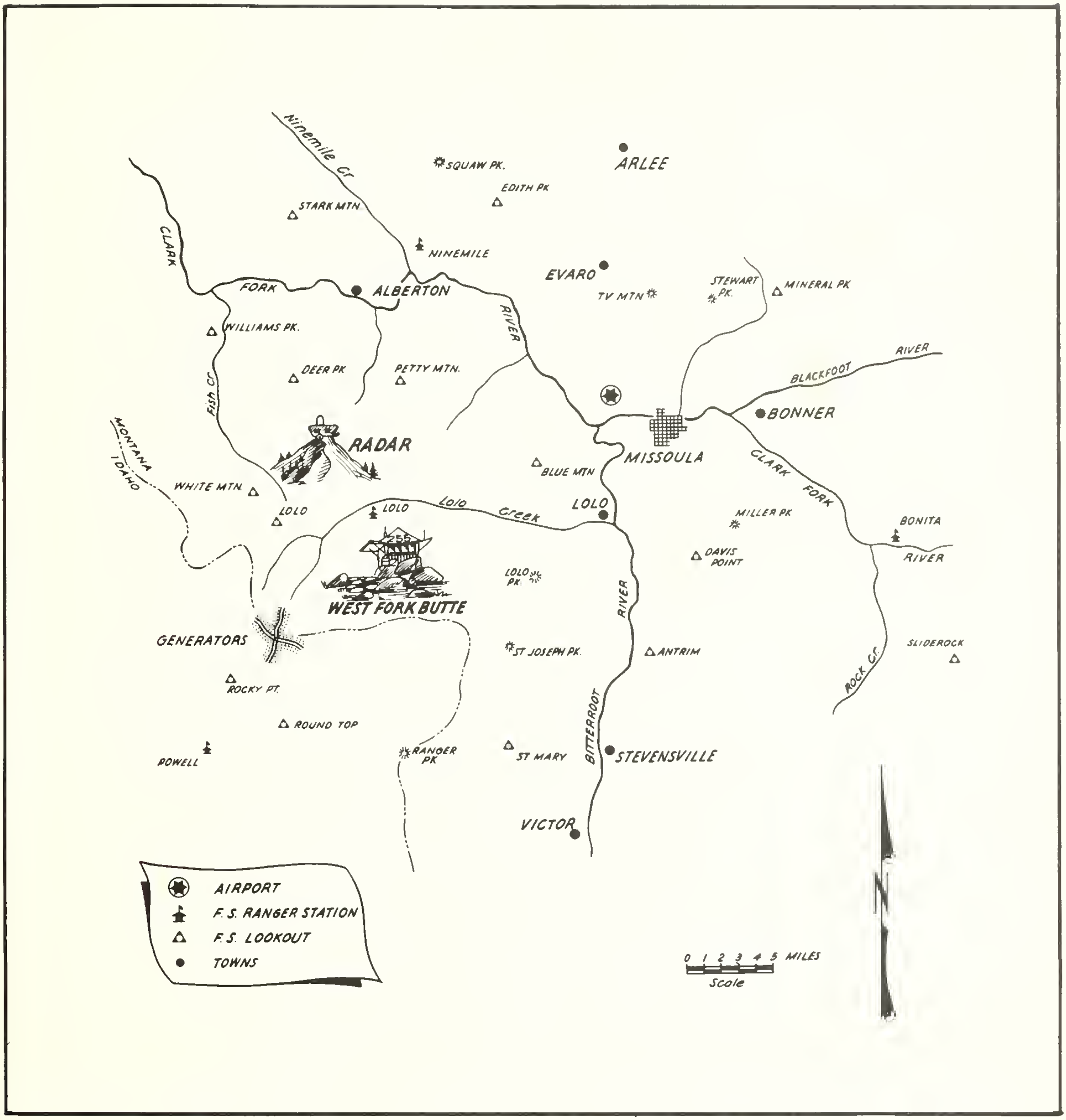


Figure 3.--Project Skyfire cloud-seeding test area on the Lolo National Forest, near Missoula, Montana.

On 24 of the 29 tests some degree of cloud modification was observed. One of the principal measures of modification is occurrence of glaciation or conversion of supercooled water droplets to ice crystals in the clouds in the silver iodide plume produced by generators. With two exceptions, glaciation

was observed wherever cloud temperatures were -4° C. or colder. The two exceptions occurred on July 9, when only one generator was operated, and on August 27, when low-hanging clouds prevented either ground or aircraft observations in the seeded area.

On 10 days during the test period extensive glaciation of the seeded clouds was observed. On each of these days cloud temperatures were -7° C. or colder. However, as shown in table 6, temperatures of -7° C. or colder do not mean that extensive glaciation always occurs. Other factors, such as moisture content and wind effects on cloud development and the silver iodide plume, influence the extent of glaciation and hence the degree of cloud modification.

Glaciation was not observed when measured temperatures were warmer than -4° C. (table 6). No glaciation occurred on July 11 and 23 and August 5, when temperatures ranged from +6° C. at cloud base to -1° C. at cloud top.

Silver iodide caused extensive glaciation in growing cumulus clouds as far as 35 miles from the generator site. Glaciation resulting from cloud seeding was photographed extending more than 60 miles from the generator site. This was the extreme limit of the observing network on that occasion.

One conclusion from Project Skyfire operations is that glaciation of both small and towering cumulus clouds invariably results from silver iodide crystal seeding whenever clouds are colder than -4° C. and whenever the silver iodide crystals are carried into the cloud. Therefore, when glaciation is observed as unique to the small test area and does not appear elsewhere in the observational network, this glaciation indicates the degree of seeding in a cloud system.

During these experiments, modification occurred in small cumulus, towering cumulus, and cloud streets 10 to 25 miles in length. Each of these cloud situations exhibited special characteristics when seeded with silver iodide. Analysis of these cloud-seeding effects has been prepared for the President's Advisory Committee on Weather Control. A report on the project's cloud-seeding results will be released early in 1958.

Cloud-Seeding Generator Development

An essential prerequisite for cloud-seeding experiments and for possible future use in lightning suppression operations is the development of a satisfactory cloud-seeding generator. A ground-based generator suitable for these purposes should have the following characteristics: ability to produce a relatively high output of silver iodide nuclei; economical and simple operation; ability to be transported and serviced easily in rough mountainous country; and be safe for use in highly flammable forests.

Several types of cloud-seeding generators were tested and calibrated. None of the generators tested were found entirely suitable. As a result, Project Skyfire carried on a program of research and development aimed at producing the required type of cloud-seeding equipment. During 1957 the

Table 6.--Summary of Project Skyfire 1957 seeding operations

Date	Generators		Freezing level	Cloud data				Glaciation in clouds in plume area
				Base		Top 1/		
	Number	Total hours		Height 2/ feet	Temperature °C.	Height 2/	Temperature °C.	
July								
8	6	19	12,000	E11,000	+2°	14,000	-4°	Fair
9	1	4	12,000	E12,000	0°	--	--	None
11	29	178	13,000	11,000	+6°	--	--	None
12	8	53	13,000	15,700	-6°	E25,000	E-25°	Good
15	9	27	11,000	10,000	+3°	13,000	-6°	Fair
16	13	84	11,000	11,700	-2°	19,000	E-20°	Good
17	30	186	9,000	10,000	-2°	13,000	-8°	Good
19	29	250	12,500	10,000	+5°	15,300	-4°	Fair
22	22	134	12,500	12,500	0°	--	--	Fair
23	26	150	12,500	9,400	+4°	12,000	+1°	None
25	11	27	13,500	14,500	-2°	E32,000	E-40°	Fair
26	14	114	12,500	11,500	+1°	--	--	Fair
29	30	156	13,000	11,500	+4.5°	E25,000	E-27°	Good
30	16	54	12,500	13,000	-1°	16,500	-7.5°	Fair
August								
5	7	15	13,000	11,300	+4°	13,500	-1°	None
6	10	44	10,000	9,000	+2°	14,000	-8°	Good
7	8	23	10,000	10,000	0°	15,000	-9.5°	Good
8	16	56	12,000	12,000	0°	14,500	-4°	Fair
9	16	56	12,600	15,000	-7°	E18,000	E-12°	Fair
14	15	98	11,000	13,800	-8°	E16,500	E-13°	Fair
15	13	91	11,700	13,500	-4°	E17,000	E-11°	Fair
16	4	32	12,000	13,600	-3.5°	17,000	-9°	Good
19	27	104	12,200	12,200	0°	20,500	-17°	Good
20	6	36	12,000	15,000	-8°	17,000	E-12°	Fair
21	15	42	11,900	12,900	-3°	E14,900	E-7°	Good
22	30	276	10,500	11,600	-2°	E25,000	E-25°	Good
23	15	81	11,900	14,000	-6°	E20,000	E-17°	Fair
27	15	86	7,800	8,300	0°	--	--	Obscured
28	15	84	9,000	10,000	-2°	E20,000	E-20°	Fair

1/ E indicates estimated.
2/ Mean sea level.

project designed and tested a highly satisfactory cloud-seeding generator. Forty of these generators were manufactured and used during the 1957 Project Skyfire experiments. The same design was used for generators operated on lightning fire experiments in California.

The Project Skyfire cloud-seeding generator shown below is a silver iodide-acetone solution burning unit with an external mixing injection system. The acetone solution is drawn from a reservoir through a modified hypodermic needle and nebulized by a jet of propane gas. The mixture of atomized acetone solution, propane, and air is directed into a flame chamber and ignited. The volatilized silver iodide condenses into crystals as the smoke passes from the flame and around a quench plate mounted above the flame chamber. The silver iodide smoke is carried away from the generator by convective currents and the surface wind. Output of this generator is 3 to 4 x 10^{13} nuclei per second effective at -20° C. when consuming 600 milliliters of 4-percent silver iodide-acetone solution and 1 pound of propane per hour at sea level pressure.

Studies of Nuclei

Cloud-seeding research involving use of silver iodide generators requires measurement of the area covered by the generators and the life and concentration of the nuclei. The project has developed techniques for these measurements and for evaluation of the results. The system involves measurement of local winds and convective activity, use of aircraft to take air samples in the silver iodide plume area, and employment of portable cold boxes in aircraft and on the ground to detect presence and concentration of both silver iodide and natural nuclei.

Project Skyfire silver iodide cloud-seeding generator being serviced in the field.

During this year's experiments 31 silver iodide plume-tracing flights were made by project aircraft shown below. These flights plus other observations of weather conditions provided data for preparing maps of the silver iodide plume area for each cloud-seeding operation. These maps greatly help in evaluating cloud-seeding results.

One major finding shows that silver iodide nuclei in the test area had a relatively low rate of deactivation. This factor is important if ground-based generators are to be used successfully in cloud-seeding operations. This year's experiments show that deactivation of silver iodide in the free atmosphere exposed to sunlight for periods longer than 30 minutes was less than one order of magnitude per hour.

The project's nuclei studies have shown that silver iodide may be used as an air tracer for many other types of research. These techniques are being used in local wind surveys important in studies of the spread of blister rust, and have wide application in micrometeorology and fire behavior research.

Radar

The mobile radar unit, developed by Project Skyfire in 1956 and used throughout the 1957 fire season in lightning fire research, was placed on a high peak in Lolo National Forest cloud-seeding test area. Returns on the radar scope showed the development of strong precipitation cells and locations and movements of lightning storms. Time lapse motion pictures of the radar scope provided a permanent record of storm systems moving across the test area and surrounding country.

Observer ready for takeoff on nuclei-tracing flight. Cold box in foreground will be mounted in right front seat of aircraft. Air samples placed in cold box during flight determine location and concentration of silver iodide nuclei in cloud-seeding test area.

Project Skyfire mobile radar unit is surplus military gear, modified for special lightning research and mounted in a 14-foot trailer. This unit detected and tracked lightning storms in cloud-seeding test area and surrounding territory.

The usefulness of radar in detection, tracking, and analysis of lightning storms has been demonstrated. Other uses, in forest-fire control, are being developed. The Skyfire radar was used once this season to predict severe winds accompanying a lightning storm moving near a going fire. Warnings of this storm movement relayed directly to the fire boss permitted the suppression crew to attack the fire more safely and effectively. Radar tracking and analysis of this storm also provided information on the location of shower zone near the fire.

As a special project, Dr. Tetsuya Fujita of the University of Chicago, Department of Meteorology, under auspices of the Munitalp Foundation, studied lightning storms with the Skyfire radar. He studied individual storm cells in relation to topographic factors as shown by ground clutter on the radar scope. The ability of radar to show topographic features also may have future value in seen area mapping for fire detection.

Cloud and Lightning Survey

For its fifth consecutive season, the network of 22 Skyfire lookout stations provided detailed information on cumulus cloud characteristics, thunderstorms, lightning, and lightning-caused fires. The network reported these conditions daily by radio to Skyfire headquarters in Missoula where cloud and lightning maps were plotted currently. These maps provided material for making useful comparisons between the cloud-seeding test area and the surrounding lookout network.

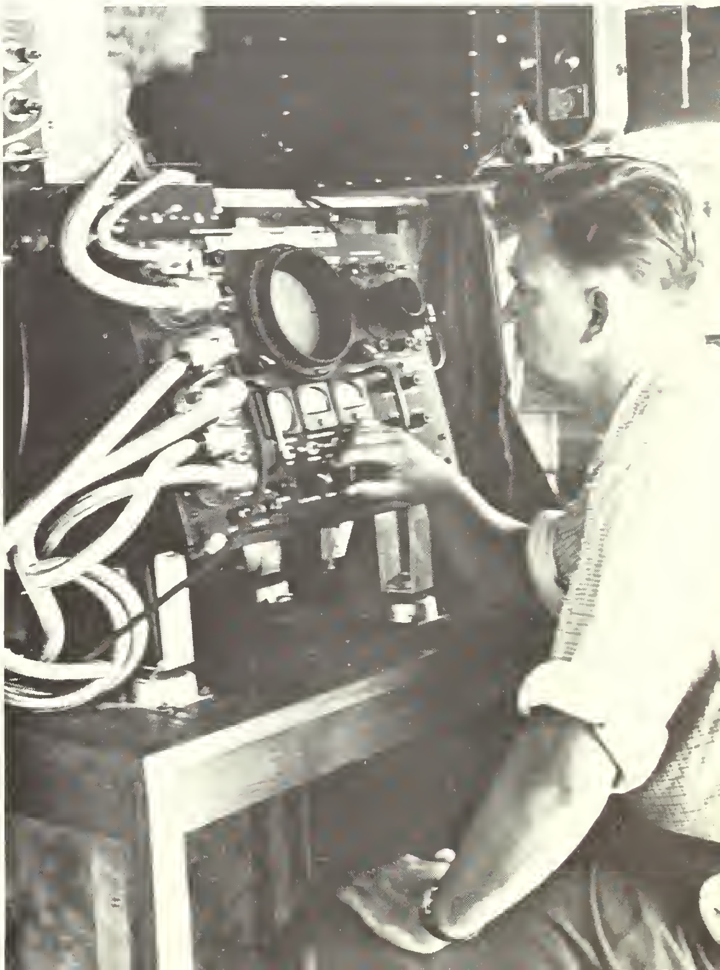
Lookout firemen at each station received 3 days of intensive instruction in cloud identification, measuring, and reporting procedures. The network functioned smoothly and provided additional information on cumulus clouds and lightning throughout the Intermountain West.

Techniques for cloud and lightning surveys have been developed and tested so as to have wide application in fire control throughout the western United States. During 1958 a lookout cloud and lightning observation handbook will be prepared. It will be a guide for fire control personnel who observe clouds and lightning for use in fire-weather forecasting and planning of fire suppression operations.

Summary of Project Skyfire Results

The principal results of Project Skyfire to date are: (1) development of basic knowledge on lightning storms and lightning fires; (2) creation and testing of a system for cloud and lightning surveys; (3) development of equipment including cloud-seeding generators and radar; (4) development of special techniques for cloud-seeding and physical analysis of results; and (5) conduct of experiments which show that growing cumulus clouds can be modified. The next major step in this research program is to determine whether the techniques and equipment used in modifying cumulus clouds can change their electrical characteristics. Experiments aimed at this objective are now being designed.

Scope of Project Skyfire mobile radar unit is monitored to obtain cloud and lightning storm information during field experiments. Time lapse camera in upper right records action from a second scope.



FIRE BEHAVIOR

Atmospheric Studies

During 1957 exploratory studies were made of fire behavior in relation to the jet stream and other atmospheric factors. Preliminary results have already been reported.[7/]

These preliminary studies involved analysis of 23 high-intensity fires occurring in 1955 and 1956, all of which exhibited unusually severe or blowup fire behavior. These fires were analyzed in relation to large-scale atmospheric patterns. Studies were made of gusty ground winds and formation of Bernard cells in relation to the jet stream; characteristics of high intensity fires under jet stream influences; and variations in atmospheric electricity and condensation nuclei in the fire areas. These studies show need for a better understanding of large-scale atmospheric factors in relation to surface conditions associated with critical fire behavior.

Fire Behavior Training

A servicewide fire behavior training school will be held at Missoula in the spring of 1958. This school will present major findings of research in fire behavior. The program includes basic meteorology, fire physics, fire behavior, fire problem solutions, and methods for training of field personnel. The staff, under direction of the Washington office, includes members of fire research staffs at forest experiment stations, regional fire control personnel, and meteorologists of the Munitalp Foundation, U. S. Weather Bureau, and Yale University. Intermountain station's Division of Forest Fire Research will develop a special training course and training equipment in fire behavior for this school.

FIRE-DANGER RATING

Fire-Danger-Rating System

The year 1957 marked the third season of use of the Model-8 burning index meter in forest protection areas of the Intermountain West. Assistance was continued to various private, State, and Federal agencies in planning location of fire-weather stations, inspection of stations, training of personnel, and interpretation of fire-danger-rating information in the planning and managing control operations. In cooperation with the U. S. Weather Bureau, the development of fire-weather operations that aid both fire-weather forecasting and fire-danger-rating activities was continued.

7/ Schaefer, Vincent J. 1957. The relationship of jet streams to forest wildfires. Jour. Forestry 55(6): 419.

Cooperation with Bureau of Land Management

Fire-danger-rating studies were continued in cooperation with the Bureau of Land Management in Alaska. The 1957 fire season was the most severe in the forests of interior Alaska since organized protection began in 1940. More than 5,000,000 acres were burned; the main damage was caused by a series of lightning fires that destroyed forest and wildlife resources and created a giant pall of smoke that seriously restricted aircraft operations. At the peak of the Alaska fire season, Charles E. Hardy, Division of Forest Fire Research, visited the Alaska fire areas to evaluate fire-weather factors, observe actual burning conditions, and make on-the-ground analysis of the experimental use of the Intermountain fire-danger-rating system.

The unusual fuels in interior Alaska are important in fire-danger rating. Vast areas have very fine fuels such as reindeer moss intermingled with the forest cover. At a critical point, fire flashes through these fuels and then ignites and spreads rapidly in heavier fuels. An important phase in fire-danger-rating research in Alaska is to determine how to interpret fire-weather factors and burning index ratings to indicate fire intensity and spread in these fuels. Fire-danger-rating factors also require study in relation to application in lightning storms, the planning of fire detection, prevention of man-caused fires, and the buildup of critical fire weather in the spring and early summer. Alaska is truly a pioneer area for forest fire research.

Fire-danger rating has major importance to the Bureau of Land Management in the West. This bureau needs methods especially for application of fire-danger-rating information in fire control on western range areas. To accelerate fire-danger rating in these areas a broad cooperative program has been agreed upon by the Bureau of Land Management and the Forest Service. The Bureau of Land Management will station a liaison officer with the Division of Forest Fire Research at Missoula. Together they will develop fire-weather measurement systems and application of fire-danger-rating methods for the western protection areas of the Bureau of Land Management.

Fuel Moisture Studies

Fuel moisture is a major factor in fire-danger rating. Gaining a better understanding of how to measure fuel moisture and how to interpret these measurements in relation to other fuel and weather factors has long been an important objective of research. The Intermountain station's study of fuel moisture includes development of techniques and equipment for measurement studies of moisture changes in various fuels, and analysis of fuel moisture factors in relation to fire season severity and buildup of conditions conducive to high-intensity fires.

Work is continuing on the maintenance of high quality in the manufacture of fuel moisture sticks and in the development of improved fuel moisture measuring systems. The one-half inch sticks manufactured at the Forest Service Spokane warehouse and used by nearly all forest protection agencies in

the West are tested for quality control during each fire season at the Priest River Experimental Forest. Weathering tests were made in 1957 in three different climates at Cascade Head Experimental Forest in western Oregon, Priest River in northern Idaho, and the Desert Experimental Range in western Utah. Three density groups of fuel moisture sticks were exposed at these locations, both under protective screens and in full sunlight. Results of this study may show how to manufacture sticks that weather less during a fire season and also how to expose these sticks to maintain greatest uniformity.

Western-type one-half inch fuel moisture sticks and eastern-type basswood slats are being studied under varied weather conditions. These studies were carried on in 1957 in cooperation with the Bureau of Land Management in Alaska and southern Idaho, the National Park Service in Utah, and by the Forest Service in northern Idaho. Results of this study may help develop better fire-danger-rating methods for fine fuels such as the grass and sagebrush stands of the Intermountain West and the tundra, reindeer moss, and muskeg areas of interior Alaska.

Studies of moisture variations of large logs in relation to fuel moisture as measured by sticks and slats and seasonlong variations in basic weather factors are being continued. Results of these studies already have contributed basic information about fuel moisture for the development of several fire-danger-rating systems used in the West. Because this study may indicate methods for predicting the buildup of a critical fire season, measurement of fuel moisture in large logs will continue at the Priest River Experimental Forest. To provide this type of data for a drier climate, a similar experiment was installed in the fall of 1957 at the Boise Basin Experimental Forest.

FIRE EQUIPMENT RESEARCH

The forest fire research program requires consideration of equipment needs and techniques of employment as well as development of special items of equipment for use in research. In addition, the Intermountain station is carrying on special fire equipment development projects aimed at designing, adapting, and testing specific items for general use in fire control.

Portable Fire-Weather Station

A portable fire-weather station has been designed and tested for use at the scene of going fires, prescribed burning operations, slash disposal work, and other forestry activities where on-the-site measurement of weather factors is needed. Packaged in a compact aluminum shelter, the 35-pound weather station contains instruments for measuring wind velocity, relative humidity, maximum and minimum temperatures, precipitation, and fuel moisture. During recent tests, this portable weather station was dropped successfully by parachute from an airplane. Final tests are now under way on 22 proto-type units already sent to various regions in the United States and Alaska for field evaluation. Preliminary manufacturing specifications are being prepared with assistance of the Forest Service, Arcadia, California Equipment Development Center.

Portable weather station set up in the field.

Fire-Weather Instruments

Research and development work on several new or improved fire-weather instruments is nearing completion. An electric fan psychrometer kit and an electric totalizing wind counter are ready for commercial manufacture. Preliminary tests have been completed on an aluminum rain gage. A small weather kit, carried in a canvas bag fastened to the belt of a forest officer, is ready for field testing. This "ranger's weather kit" contains a sling psychrometer, venturi tube-type wind meter,psychrometric slide rule, plastic water bottle, miscellaneous weather forms, and burning index meter.

Recording Fire-Weather Stations

Two types of automatic recording fire-weather stations are in the preliminary development stage. One type records readings of wet and dry bulb temperatures, wind velocity, time, and fuel moisture by a photographic process. The first photographs have been obtained from the battery-powered experimental model designed to record measurements at forest stations that cannot be manned at the time set for fire-weather observations. The second unit, now ready for initial assembly, is a continuous recording fire-weather station. Designed for use at key fire-weather stations and on special projects requiring continuous weather data, this battery-powered equipment records wet and dry bulb temperatures, wind velocity, and fuel moisture once each hour.

Knock-down Aluminum Instrument Shelter

At regular fire-weather stations meteorological instruments must be sheltered and exposed in a standard manner so as to give accurate and uniformly consistent readings. Furthermore, at many stations such as fire lookouts, the shelter and the instruments must be dismantled during the winter months to prevent damage by severe weather. To meet these requirements, a new type knock-down weather instrument shelter has been designed; pilot models have been built and tested. Aluminum was selected as the basic material in an attempt to save weight, promote ease of assembly and disassembly, and take advantage of possible savings through use of metal stampings. Tests made by the Instrument Division of the U. S. Weather Bureau show that this new instrument shelter varies less than one degree from temperature readings made in a standard Weather Bureau cotton region-type instrument shelter.

Controlled Temperature-Humidity Cabinet

This year the Division of Forest Fire Research completed design and construction of a controlled temperature-humidity cabinet. This equipment will be employed in analyses of moisture content of forest fuels, testing of relative humidity measuring devices, measurement of changes in fuel moisture sticks and calibration of instruments used in fire-weather operations. This equipment is a forerunner of a larger, more fully controlled unit planned for inclusion in a proposed forest fire laboratory.

Advanced Equipment Research

Several possibilities for development of new types of fire equipment were studied by the Division of Forest Fire Research this year. These possibilities include: (1) an electronic instrument to count and locate lightning strokes for use at fire lookout stations; (2) adaptation of radar for seen area mapping in fire detection studies and use in mobile weather units for predicting thunderstorm induced winds and precipitation areas; and (3) modification of surplus military range finders for use in cloud measurements and observation of forest fire smoke columns. Also, studies on the development of research facilities and equipment for a proposed forest fire laboratory were continued.

LOGGING SLASH RESEARCH

During 1957 flammability tests of 5-year-old chipped logging slash were completed at the Priest River Experimental Forest. Burning this slash showed that all species and all quantities had very low flammability. Chipping causes an immediate and large reduction in flammability; therefore the 5-year-old plots showed no great change from the results obtained in burning fresher chipped slash.

A logging slash review was held in the fall of 1957. Personnel from Forest Service Regions 1, 2, and 4 and the Rocky Mountain Experiment Station observed logging slash operations at the Priest River Experimental Forest and on the Kaniksu, Kootenai, Deerlodge, and Lewis and Clark National Forests. Special attention was given to results of logging slash research and methods of slash treatment in the Engelmann spruce and lodgepole pine types.

Analysis of slash measurement methods was continued. Results show that quantity of slash from cutting a given stand can be estimated with acceptable accuracy from measurements of standing trees. Crown weight is proportional to the product of d.b.h. and crown length. Tables of crown weight by d.b.h. classes have been prepared using average crown length values. Although subject to considerable error if used to estimate the crown weight of an individual tree, these tables can be used in conjunction with stand tables to obtain satisfactory estimates of slash weight per acre. Greater accuracy can be attained by measuring representative crown lengths in each stand to be estimated. Weight of slash per M bd. ft. cut varies widely with species and size of material.

Studies of fire spread in slash were continued. Results of experimental burning indicate that rising relative humidity proportionately reduces rate of fire spread. While the actual reduction is greatest in light concentrations of fuel, percentage reduction is approximately the same for all weights per acre. During the year of cutting, quantity of slash is the main factor affecting rate of spread, although lesser effects of species characteristics are noticeable. Thereafter species becomes more important because of differences in rate of decomposition.

Fire intensity, measured in terms of heat radiation, closely parallels rate of spread. Because of the large quantity of attached foliage, raised from the ground and well-aerated, fires are especially hot in heavy concentrations of fresh and 1-year-old western white pine and lodgepole pine slash and fresh Douglas-fir and grand fir slash. When a large area of slash is burning rapidly, flames reach high into the air and often pulsate rhythmically. Ignition of gases in the convection column above the main body of flames occurs commonly. The maximum emissivity of slash fires approximates 0.30.

FOREST SURVEY

The national Forest Survey program provides for inventory of all commercial forest land in the United States and for periodic reinventories of these lands to keep the resource data current. The Forest Survey Unit of the Intermountain station carries out the survey program in all the Rocky Mountain states from the Canadian border to Mexico and in the Black Hills portion of South Dakota. This territory embraces nearly one-third of the land area of the United States, about 22 percent of the forest area, and 11 percent of the commercial forest area.

The initial survey has been completed in Montana, Idaho, and South Dakota; it covers about one-third of the forest area of the Rocky Mountains. The area including Wyoming, Utah, Nevada, Colorado, Arizona, and New Mexico is the only portion of the United States not yet covered by the Forest Survey. Initial surveys are progressing in Colorado and Wyoming. A reinventory survey has been completed in northern Idaho and is now under way in western Montana.

Initial Survey

For the last 2 years the field program has been concentrated in Colorado and Wyoming. The survey has been closely coordinated with the forest management inventory program of the national forests in Regions 2 and 4. Regional personnel have delineated forest cover on aerial photos, have transferred these delineations to base maps, and have computed area of the various types and stand-size classes. Forest Survey crews have located field plots from points pinpricked on aerial photos and have carefully measured and recorded tree dimensions and conditions. All field data have been assembled and reviewed by the Intermountain survey staff and forwarded to the California IBM Unit[8/] for machine tabulation.

During the year, twelve 2-man survey crews completed field work on nearly 6 million acres of forest land in Colorado of which approximately 2.6 million acres were commercial forest land. This is about 28 percent of the commercial forest area of the State and brings the completion rate for the 2-year period to 54 percent. Two more field seasons probably will be required to complete the survey in Colorado.

In Wyoming, field work was completed on 722,000 acres of forest land (688,000 acres of commercial forest land) on the Medicine Bow National Forest in cooperation with Region 2; and 607,000 acres of forest land (594,000 acres commercial forest land) on the Teton National Forest in cooperation with

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8/ Operated by California Forest and Range Experiment Station as a Service Unit for the California, Intermountain, and Alaska Experiment Stations.

Region 4. About half of the commercial forest area in Wyoming has now been covered by the Forest Survey. At the present rate, field work for the entire State will be completed in 2 more years.

An interesting feature of the cooperative field program on the Teton National Forest was use of a helicopter to transport field men to plots in the back country. This program, developed and carried out by Region 4 with Forest Survey assistance, eliminated need for organizing pack trips. Preliminary reports on this program indicate that the cost per plot for transportation by helicopter was about the same as by pack train but that the helicopter saved considerable time; that is, the same number of men completed survey of a given number of plots in less time by helicopter than by pack train. This may mean that mechanization has caught up with timber cruising and that the traditional string of pack animals and riders will disappear from timber surveys of the back country.

Maintenance Survey

Field work on the reinventory of forest resources of western Montana was continued at full scale during the year in close cooperation with the Timber Management division of Region 1. The Bureau of Land Management also assisted by field examining survey plots on BLM land. A total of 2.9 million acres of forest land was covered, of which 2.2 million acres were commercial forest land. The area of commercial forest land in Montana covered by the reinventory is now 7.6 million acres, or nearly one-half of the State total.

Plans for 1958 provide for completing the reinventory in western Montana on both public and private land. Profiting from the helicopter experience gained on the Teton National Forest, preliminary plans have been made for using helicopters to transport survey field men to plots in remote portions of the Flathead National Forest next summer.

Timber Cut

In cooperation with the Bureau of the Census, surveys of lumber production in 1956 were made for Idaho and Montana. Lumber production for the year set new records in both States. Idaho's mills sawed 1.6 billion board feet, while Montana's mills produced 981 million board feet.

In Idaho, Douglas-fir, true firs (mostly grand fir), and ponderosa pine accounted for nearly two-thirds of the total production (see following tabulation). Engelmann spruce was the principal species cut in Montana, chiefly because of intensive efforts to harvest timber killed or infested by the spruce bark beetle.

Lumber production in Montana and Idaho, 1956

Species	Montana	Idaho
	Millions of board feet	
Douglas-fir	237	399
Engelmann spruce	340	221
True firs	9	305
Ponderosa pine	157	304
Western white pine	39	184
Western larch	147	125
Other	52	71
Total	981	1,609

Concurrently with the lumber production study, surveys of the 1956 output of other primary products were made for determining the total volume of timber cut in Idaho and Montana. Results of the pole production survey have been published, and data for other products--sawlogs, veneer logs and bolts, pulpwood, mine timbers, and miscellaneous products--are being compiled.

The pole production survey, made annually in cooperation with the Rocky Mountain Pole and Treating Association, covers northeast Washington, northern Idaho, and Montana. The 1956 survey showed a total production of 577,650 poles, almost double the 1955 total. Lodgepole pine was the leading pole species in 1956, as shown in the following tabulation:

Species	1955	1956
	Thousands of pieces	
Western redcedar	132	194
Lodgepole pine	95	237
Western larch	62	111
Douglas-fir	6	36
Total	295	578

The survey of Montana Christmas tree shipments is also made annually. In 1956, the all-time record of 4.2 million trees was shipped out of Montana by rail and truck. Flathead and Lincoln Counties, the leading producing areas, accounted for nearly two-thirds of the total production.

Aerial Photo Interpretation

Probably the most significant development in aerial photo interpretation research during the year was publication of Preliminary Aerial Volume Tables for Conifer Stands in the Rocky Mountains. The tables, prepared from photo and field measurements of the same plots, enable the estimation of timber volume directly from the photographs. By measurement of tree heights, crown widths, and stand density on the photos and application of the aerial volume tables, a trained interpreter can quickly obtain volume data that are adequate for preliminary appraisals, volume estimates of inaccessible or low value stands, or for estimates of serious disease or insect losses. The tables are designated as preliminary because additional plot data are needed to assure better accuracy. Tests of their accuracy in various parts of the Rocky Mountain area are also needed to aid in determining their applicability. Tests made in cooperation with Forest Inventories Research Section of the Canadian Government at Ottawa indicate that aerial stand volume tables of this kind may also be adapted to Canadian timber stands, particularly for obtaining volume estimates for the large areas of inaccessible timber in the northern portion of the provinces.

Other photo research has included testing the accuracy of making area determinations by dot sampling on photos and preparation of training aids and manuals. A joint publication by this station and the Washington office gives detailed instructions for use of the parallax wedge in photo measurements. During the year Karl Moessner has conducted photo training courses for station and region personnel, industrial foresters, and forest school students.

FOREST ECONOMICS

In recent years the economic studies made by this station have been directed primarily to the problem of describing in broad terms the opportunity for development of the timber industry in this part of the Mountain States and the present and ultimate place of timber in the economy of the region. These states have millions of acres of commercial forests only partly developed. If management is to be properly oriented to produce the greatest long-range benefits, it is important to have a realistic appraisal of the forests' place in the regional economy.

Three reports aimed at this problem were published in 1957. Research Paper 50, Market Prospects for Mountain States Timber, reviewed the national long-range timber growing task with special emphasis on what the national wood production means as timber opportunity in the Rocky Mountain area. The conclusions presented are encouraging. Lodgepole Pine, A Lumber Species analyzed the qualities of this species for lumber as well as some of the problems involved in expanding use of it. Since the 14,000,000 acres of this type in the West have had little logging to date, this paper has special interest and significance. The third paper in this group, Industrial Opportunities in the Headwaters Timber Development Unit, analyzes development problems and opportunities of an individual area. The Headwaters Timber

Development Unit includes southeastern Idaho, western Wyoming, and a bit of northern Utah. Except for the hewed tie operations of the past and the scattered cutting of small sawmills, there has been little use of the timber in this area. This is one of the localities where considerable development will be made in years to come.

Another investigation, currently in process, goes beyond considerations of just the forest resource and evaluates the economic potential of the Mountain States area as indicated by its minerals, farmlands, water, and other physical resources. This study also is attempting to determine whether aridity, or lack of resources, or some other basic factor imposes a low ceiling on the prospects for regional growth, or whether, on the other hand, the region still has considerable opportunity for growth. The over-all economic outlook is an important consideration in forestry and other planning.

A general study of the lumber transportation problem was started in 1957. Railroad waybill statistics compiled by the Interstate Commerce Commission and other data are being studied to determine long-range trends in lumber distribution that affect the marketing of Rocky Mountain lumber. The waybill statistics also contain useful data on rail freight costs. This analysis should bring some of the marketing problems and opportunities into clearer focus.

Work was begun this year on analysis of opportunities for the timber industry in the Clark Fork Timber Development Unit in western Montana. This has long been an important lumber-producing area, but it suffers from the lack of fiber-using industries. Regional Forester Tebbe has requested this study to reevaluate industrial needs and opportunities. Attention will also be given to the matter of forest management needs if industrial objectives are to be realized.

Preliminary steps were taken in 1957 toward building parallel economics research programs in the range and watershed fields. The growing conflict over rangeland use obviously cannot be resolved without looking beyond the land itself to the broader question of how use of the land affects the hopes and aspirations of the region. A much more complete measure of long-time water values is necessary. We need to know how important the wild-land forage is to the agricultural economy and to the total economy. Certainly one reason the range problem has not been met decisively has been that the issues and alternatives have not been clear-cut. It is to be hoped that broad economic studies of range and watershed can provide that clarification.

FOREST UTILIZATION RESEARCH

Forest Utilization Research performs a unique and distinct function in the Intermountain station. This is by far the smallest unit, and it conducts the least amount of direct experimental research; yet it has at its fingertips the largest single research unit of the Forest Service, namely, the Forest Products Research Laboratory at Madison, Wisconsin. No other phase of the research program is so organized. The Forest Utilization Research division acts as the eyes and ears of the Forest Products Laboratory and aims to perform a threefold function:

1. To evaluate needs for research in forest utilization and to see that these needs are met.

2. To put the results of utilization research into early effect.

3. To conduct research for which it is technically equipped or which can be done best in the field.

Behind this entire program lies deep-rooted belief that utilization of products from the forest is the ultimate. Broadly, this philosophy extends to all other branches of forest research. Research in this division is restricted to use of the timber resource: timber growth without timber use would be futile. The intent of this division is to assure increasingly improved use of the timber resource.

Previous years have seen vast increase in the number of wood-using industries throughout Intermountain station's territory. However, business conditions during 1957 forced many companies to delay or curtail planned programs of expansion. A few of the smaller, marginal sawmills have ceased production altogether; many other mills have been forced to restrict their output. Despite this temporary setback, the region has great potential both for growth of established industries and also for development of new industries. The program of utilization research is closely associated with the long-term resource development of the region. During 1957 some progress was made towards accomplishment of this objective.

TIMBER GROWTH AND UTILIZATION RESEARCH

The staff is actively interested in developing sound usable log grades. This is no short-term program but will have to continue over a number of years. The ultimate goal of this program is to develop log grades that will differentiate between the qualities of standing trees. During the year the staff attended several meetings of the regional log grade committee, and represented the station at the National Log Grade Committee meeting at

Quincy, California, and at the Timber Quality Conference at Madison, Wisconsin. This latter meeting stressed the importance of timber quality in the forest survey, forest management, and forest utilization programs, and also emphasized need for more and better log- and tree-grade studies.

Eight lumber-grade studies were started or completed in 1957. Final data were collected for the Douglas-fir study started in 1956. This study was designed to develop criteria for Douglas-fir log grades and to determine the effect of compression wood on lumber grade yield. Trees having varying degrees of lean were selected in the woods; then they were felled, bucked, and milled, and the lumber yield was graded and tallied green, dry, and after 6 months' storage The Forest Products Laboratory is responsible for the analysis and publication of these data.

One of a series of studies of white pine was made at a sawmill in Superior, Montana. This particular study was designed to determine the effect of sawing method on the quality and quantity of the lumber yield. Trees for this study were selected in the woods and, after felling and bucking, all logs were diagramed. Four different methods were used to saw the logs The lumber was graded and tallied green, after drying, and after surfacing. Analysis of these data also will be prepared by the Forest Products Laboratory.

Loggers and sawmill managers have shown great interest in the problems of harvesting steep mountain watersheds and lodgepole pine stands. We hope to direct this interest toward organizing a logging committee that will evaluate existing equipment and encourage development of new equipment that will meet the special needs of this mountainous country.

Two experimental studies of the effect of spiral grain on the twisting of poles in service are now nearing completion. The study at Newport, Washington, probably will be completed in 1958, but collection of data at the Libby, Montana installation will continue.

Several projects have been undertaken to help sawmill operators. One has been a series of clinics designed to meet needs of some of the 1,000 small mills in our area. Their chief problem is to make better quality lumber at cheaper cost, to use raw materials more efficiently, and to improve their marketing. The larger mills have problems of a different type. Some companies have broadened their product base to include paper-overlaid lumber, edge-glued lumber, and laminated dimension. Each of these new products brings results of earlier research into commercial use; and by the same token each new manufacturing venture is accompanied by new needs for research.

One of the major changes in the operation of lumber companies in recent years has been the great increase in storage of logs on dry ground--"cold decks," as they are called in the trade. Reasons for this change are many, and new problems in log deterioration have accompanied the change. A major study conducted by the station this year at Libby, Montana, was designed to

measure deterioration and to provide guidelines for corrective action. Results of this study will be reported separately; but, in brief, they show that logs kept moist by artificial spray neither decay nor check; that application of this spray on log ends is important; and that more power is required to saw dry logs than wet ones.

PULP AND PAPER

Long-term efforts at developing outlets for wood fiber-waste wood have been rewarding. The most prominent advance in fiber utilization has been the completion, late this year, of a new kraft pulp mill near Missoula, Montana,with designed capacity of 250 tons per day. It was built by the Waldorf Paper Products Company and will use chipped residues from numerous mills located within a 100-mile radius; pulp processed here will be shipped to Minnesota for processing. Establishment of this mill should go far towards bettering the wood utilization procedures of chip suppliers. Installation of barkers at numerous mills has provided outlets for sawmill residues previously unusable. The enforced use of barkers will establish their merit and may point the way for their use in other sawmills in the territory. The Waldorf mill has incorporated many important features of advanced engineering design; its nearly complete chemical recovery processes result in tremendous reduction of stream pollution from effluents.

Construction of a paper mill by the St. Regis Paper Company at Libby, Montana, has been delayed, but the company is making additional studies of wood residues with a view to eventual construction. The Boise Cascade Corporation has announced plans for a corrugated container plant at Burley, Idaho.

It is hoped that additional pulp and fiber industries will become established within the station territory, for the supplies of wood and water necessary to support such industries are ample. The division has concentrated effort on finding suitable sites for new pulp mills, has given technical assistance to the lone particle board manufacturer in the region, and has fostered the construction for increased capacity at established pulp mills.

PHYSICS AND ENGINEERING

Reevaluation of basic strength properties of inland Douglas-fir has aroused considerable controversy in the Intermountain region. Significance of this tremendous problem is evident from the increases in Douglas-fir production, and many companies are planning to increase their production still further even though they foresee marketing problems arising from assignment of differential strength values. The lumber industry is alert to problems raised by the Forest Products Laboratory report on Douglas-fir strength, and has promised to cooperate with the laboratory in resolution of these problems. This division continues to work closely with representatives of industry in attempting to establish workable values for Douglas-fir strength ratings.

The recent mill study at Superior, Montana, emphasizes importance of well managed and operated dry kilns. This mill, cutting only white pine, is experiencing difficulty in drying water-core stock. Mixing this material with normal run lumber results in a wide range of moisture content after drying. Either segregation of stock or special drying procedures may be needed to alleviate this problem. The problem emphasizes need for additional kiln studies and for training in kiln operation.

TIMBER PROCESSING

Uncertainties of the present market have drastically affected the plywood and particle board companies in this territory. Two plywood companies and the single particle board plant stopped operation in the fall even though the particle board company had announced plans for a new plant plus additions to the old one. These companies all expect to resume operations as soon as market conditions become favorable.

Two operators in the region have evidenced interest in production of paper-overlaid lumber. Information supplied by the Forest Products Laboratory has been the basis of their studies to date; but additional promotion and publicity are needed before full-scale production can be started.

One major problem is utilization of narrow and short boards obtained from lodgepole pine. Several companies have started edge- and end-gluing operations aimed at producing wide, clear boards of the higher grades. As other companies install gluing equipment and attain adequate gluing experience, the region should benefit from increased utilization and from manufacture of an increased variety of products.

WOOD CHEMISTRY

Establishment of a charcoal industry within the region is well within the realm of possibility. Thus far, interest in this project has been intermittent, but it has been spurred lately by the popularity of home barbecuing. Latest and best sustained interest has been shown by the Rural Development Committee for Lincoln County, Nevada. This group is investigating possibilities of producing charcoal from pinyon and juniper. Both these trees are characteristically so small sized that considerable research will be necessary before any commercial operation can be started.

RANGE MANAGEMENT RESEARCH

Highlights of range-research problems in the southern part of the station territory were described in the 1952 Annual Report. Last year's report presented an outline of range-research problems in Montana. This year an outline of range-research problems is presented for the Inland Empire Research Center territory in northern Idaho and northeastern Washington. Space permits giving only the highlights, a few basic facts, and a summary of the conclusions.

RANGE PROBLEMS AND RESEARCH NEEDS IN THE INLAND EMPIRE

The area served by the Inland Empire Research Center contains nearly a half million people and 20.45 million acres. Two-thirds of the people and 7.88 million acres are in northeastern Washington; one-third of the people and 12.57 million acres are in northern Idaho.

Almost 50 percent of the land within the Inland Empire is privately owned, 45 percent is federally owned or managed, and 5 percent is owned by states and counties. In northeastern Washington 72 percent of the land is privately owned, but in northern Idaho only 36 percent: this difference reflects relative suitabilities of the land for agriculture.

Forest covers 70 percent of the total land area, cropland 20 percent, and low-elevation grassland the remaining 10 percent. Forest land occupies half the land area in Washington, but four-fifths of the land area in northern Idaho.

Low-elevation grasslands are dominated by a variety of bunchgrass associations. Most of the grassland has been so badly depleted by overgrazing that little of the original perennial cover remains, and considerable invasion of undesirable exotic plants has taken place. Relatively small forest openings occur as mountain meadows and high-elevation herblands.

Forested lands have been classified into four major climax-vegetation zones, each composed of one or more associations. The driest zone is dominated by ponderosa pine, which forms open stands with an undergrowth of herbs and shrubs. The somewhat moister Douglas-fir zone has a denser cover of trees and an understory vegetation predominantly of shrubs. The cedar-hemlock zone has special importance in northern Idaho, for here western white pine occurs as a major seral tree. A subalpine forest zone is dominated by Engelmann spruce and alpine fir.

Forest land in northeastern Washington is largely within the ponderosa pine and Douglas-fir zones, much of it in seral stages dominated by lodgepole pine and western larch. Northern Idaho has land in all four forest zones, including extensive areas in seral stages of the cedar-hemlock. Approximately one-third of northern Idaho is considered noncommercial in terms of timber production; this land is chiefly valuable for watershed, wildlife, and recreation.

Enormous areas of forest in Idaho and Washington were devastated by fire early in this century. The most extensive fires occurred in 1910 when almost one-fifth of the total forest area in northern Idaho was burned. Other large fires occurred in 1919, 1926, 1929, 1931, and 1934. Many of these burned areas have not yet reverted to forest but persist as extensive brush fields. Nearly one million acres of commercial forest land in northern Idaho remain deforested, it has been estimated, primarily because of double burns.

Roughly 7.2 million acres, or 35 percent of the Inland Empire, is grazed by domestic livestock. The significance of forested land to the livestock industry is indicated by the fact that 73 percent of the total area grazed is forest range. Thirty-seven percent of the 14.6 million acres of all forested land receives grazing use by domestic livestock. Forest lands are also the principal habitat for large herds of deer and elk.

Livestock numbers have varied considerably during the past 30 years. In 1925 the area supported almost 200,000 sheep and 187,000 cattle. Sheep have decreased greatly since 1935 and cattle have increased: in 1954 there were almost 70,000 sheep and 373,000 cattle. Estimated value of all livestock in the Inland Empire in 1954 was 38¼ million dollars, of which cattle accounted for 95 percent.

Any accurate estimate of the value of the big-game resource is impossible. A computation can be made of expenditures by hunters--it is estimated that between 6 and 10 million dollars are spent annually in the Inland Empire area by hunters seeking deer and elk--but no dollar figure can be applied to the many intangible values of wildlife. One economist estimated that in the entire state of Washington big-game values were equal to 27 percent of all cattle values and 8 percent of all livestock and products. The proportions are undoubtedly much greater in the northeastern part of the State. Because of the large elk and deer herds in northern Idaho, and lesser agricultural activity, the comparative value of big game there is probably much greater than in Washington.

From 1952 to 1955 the annual big-game harvest in the Inland Empire was between 18,000 and 28,000 deer and (practically entirely in northern Idaho) between 5,000 and 9,000 elk. Because of inaccessibility to hunters, it is doubtful whether the elk harvest is equal to the herd potential. Elk are not readily taken in remote areas that can be reached only by pack-string or airplane.

The extensive forest fires mentioned above created vast brush fields and the bounteous big-game habitat responsible for a general buildup of deer and elk during the 1930's and early 1940's. As these brush fields revert to conifers or the shrubs attain heights beyond the reach of animals, progressively less usable range is available. This, combined with reduced fire occurrence and overuse of critical key winter areas, has gradually resulted in a general leveling and even decreases in animal numbers. During severe winters deer and elk are forced to concentrate on very restricted areas along river bottoms and southern exposures at the foot of slopes. These extreme concentration areas are considered critical for maintenance of the big-game herds.

Problems

An outline of broad problems, not necessarily in order of priority, follows:

1. Open low-elevation livestock range (mainly used in fall, winter, and spring)

    a. Management of nondepleted areas
    b. Restoration of depleted areas
    c. Control of undesirable plants

2. Timbered range

    a. Economic relations of timber and forage
    b. Management of permanent forest ranges (mostly ponderosa pine zone, used in spring, summer, and fall)
    c. Management of transitory forest ranges (mostly Douglas-fir and cedar-hemlock zones, used in summer)

3. Mountain meadow summer range

4. Open high-elevation summer range

    a. Management of fair- to good-condition range
    b. Restoration of depleted areas

5. Big-game range

    a. Restoration and maintenance of winter range
    b. Economic relations of big game and other resources
    c. Conflict between big game and timber
    d. Conflict between big game and livestock
    e. Conflict between big game and watersheds
    f. Conflict between different kinds of big-game animals

Priority Evaluation

Economically the livestock resource probably has greater importance than big game in the Inland Empire, but the significance of big game, not only as a resource in itself but as an influence on other resources--timber, water, and livestock--is enormous.

Despite the importance of big game to this area, comparatively little has been done to determine suitable methods for management of its habitat. The seral-shrub game habitat in the Inland Empire is unique as a problem type, whereas studies conducted on livestock range throughout the Northwest and northern Rocky Mountain areas can often be applied to livestock range in this area. As a result, the need for research on big-game ranges is believed to be greater than that for livestock ranges in the Inland Empire.

Winter ranges are the limiting factor in controlling big-game numbers in this area; summer ranges appear ample at present. In order to sustain the big-game resource, winter ranges must be maintained in productive condition.

Although the bulk of livestock-grazing land in the Inland Empire is forested, the most critical problems are on high-elevation openings. These are small in area, but when in good condition they are highly productive. Of still greater importance is their sensitivity to irreparable damage from grazing abuse. When their ground cover is disturbed appreciably, the soils erode and both watershed and forage values may deteriorate rapidly. Many areas are eroding at present. The key nature of these areas requires that they be given high priority in research for development of suitable grazing-management and soil-stabilization practices.

Forested range is not so sensitive to damage as the high-elevation openings. However, because of the dominant place of forest ranges in the total grazing resource of the Inland Empire, and because here livestock use must be integrated with timber and wildlife production, the forest ranges should rank high in priority for study. Work on permanent forest range should take precedence over that on transitory forest range, for the former consists of areas that are continually used as grazing lands and must be maintained in satisfactory condition. Transitory ranges are a resource that can be used by livestock for only a few years following timber harvest. The problem of transitory range is largely that of developing a shifting grazing resource compatible with timber production on areas where the primary function is growing trees.

Mountain meadows, despite their small area, are an important source of summer grazing. Most are fairly productive even in poor condition and apparently do not erode until severely depleted. For these reasons research problems of mountain-meadow management are ranked fairly low in priority.

Open, low-elevation livestock ranges are also included in the lower priority classifications. These areas involve less than 25 percent of the total grazing lands. Their only use, aside from minor watershed values, is for livestock grazing. A very great part of this range is depleted, but soil erosion does not appear to be a major problem.

The greatest research deficiency is lack of adequate ecological understanding of the various range types. Achieving full use of the grazing resource and developing sound management practices demand fundamental knowledge of vegetation structure, successional patterns, and how these are affected by grazing. Because this basic information is either sketchy for most areas or lacking entirely, synecological studies and studies of grazing effects are given high priority.

Of major importance also, regardless of range type, is the description and interpretation of indicators of range condition and trend. Such indicators are a vital management tool; their development is directly allied with synecological studies and should receive high study priority.

Project Program

Restrictions in personnel to one permanent man with a summer assistant necessitate careful direction of research effort where it will do the greatest good. Outlined below, in approximate order of priority, are studies for the high-priority problem areas. Only those problems are included that are considered approachable with present resources by 1961.

Big-Game Winter Range

1. Describe the seral shrub complexes that occur in forest-climax zones of the Inland Empire; correlate with stages in succession to the climax-forest type, with different intensities and composition of tree overstory, and with past treatment. Special attention should be given to big-game winter range, but study will apply to livestock transitory forest range as well.

2. Determine the forage value of common shrub species for big-game animals and the effects of degree of utilization. Develop browse utilization standards.

3. Determine the phenology and reproduction methods of primary browse species.

4. Determine methods for returning to available production browse that has grown beyond the reach of game animals.

Open High-Elevation Livestock Range

1. Describe subalpine herblands, their soil and other site characteristics, and classify the plant communities in terms of range-watershed condition.

2. Determine the influence of degree and period of grazing use upon soil stability and forage production.

Livestock Permanent Forest Range

1. Describe the plant communities on the basis of existing classifications, in order to better understand composition and distribution of understory vegetation, primarily in the ponderosa pine zone.

RANGE TREND OVER 25 YEARS ON THE BOISE RIVER WATERSHED

A serious erosion problem has long been recognized on the Boise River watershed. Approximately 7,500 acre feet of silt is estimated to have been deposited in the reservoir during the 12 years following completion of Arrowrock Dam in 1915. Accelerated erosion probably began shortly after the introduction of large numbers of livestock into the country about 1880 and has been continuing ever since.

The Boise River watershed is characterized by exceedingly steep slopes, narrow ridges, and numerous deep, V-shaped canyons. The soil, which is derived from granite, is coarse, loose, and easily disturbed. The perennial vegetation is chiefly a mixture of bunchgrasses and forbs with Agropyron inerme, Poa secunda, Balsamorhiza sagittata, Astragalus canadensis, and Lupinus spp. prominent at the lower elevations. Shrubs, which dominate certain areas, are mainly Artemisia tridentata, Purshia tridentata, Prunus emarginata, and P. virginiana. The most common annuals are Bromus tectorum and Gayophytum spp.

A system of plots and chart quadrats was established in 1931 in the drainage of the South Fork of the Boise River. The plots were inventoried frequently from 1931 through 1940. In 1940 the project had to be discontinued, and no further observations were made until 1955 and 1956. This report includes salient facts gleaned from study of the plots at the lower elevations (3,900-5,100 ft.) over this 25-year interval.

It is obvious that range improvement, based on several criteria, has taken place generally throughout the watershed. In 1931 about one-third of the plots were dominated by annuals, mainly cheatgrass and Gayophytum; in some areas annuals exceeded perennials on nearly every plot. In 1956 annuals were dominant on only one-tenth of the plots.

Cover of living perennial grasses, forbs, and shrubs, with few exceptions, has increased. In some areas these changes in cover were accomplished by increase in certain species and concurrent decrease in other species. In other plots the species behavior may have been exactly reversed, and this brings into focus the matter of secondary succession following disturbance of the original vegetation by overgrazing.

The pattern of secondary succession appears to be fairly clear-cut on one area, and hints of a similar pattern appear on others. It begins with cheatgrass at the time the plots were established and proceeds from that to Poa secunda and then to a mixture of Agropyron inerme and Koeleria cristata. Broad leaved forbs such as Balsamorhiza sagittata, Astragalus canadensis, and Lupinus spp. are important components of the vegetation, and abundant evidence indicate that they probably modify the microenvironment favorably toward establishment and spread of perennial grasses. Evidence also indicates that decreases in perennial grasses may be associated with concurrent increases in perennial forb or shrubs.

On some plots, most of the total change recorded over the span of 25 years occurred during the first 10 years of record; on others most of the change came sometime after 1940, but we cannot tell exactly when because we have no record between 1940 and 1955. On still others the change was apparently continuous over the entire period. These differences, both in species behavior and in the time element, are very likely related to differences in sites and in stages of secondary succession at the time the plots were set out.

In general, the plots in worst condition today, including those that have shown the least improvement (or none at all) are those having southerly aspect. On a few plots that failed to improve, even though they presumably started out in 1931 in the same stage of succession and with the same opportunities as others that did improve, there is indication that trampling disturbance by cattle may have caused the failure. There is also some indication that soil sloughing, which is prevalent on this watershed, is responsible for the erratic behavior of some species, particularly Agropyron inerme. A plant becomes established; then the soil sloughs away; the roots are exposed and the plant dies; another plant comes in and the process is repeated, so the slope is never really stabilized and the amount of cover merely fluctuates.

The quadrat charts show that many individual plants of the common perennial grasses, forbs, and shrubs are at least 25 years old. Some are much older because they were large plants when first charted in 1931. The fact that these old-timers have persisted throughout the period of record and longer on the loose soils that slough so easily lends support to the belief that portions of this country are improving--or at least holding their own against the impact of raindrops, grazing animals, and rodents.

CHEATGRASS ECOLOGY

Phenological observations were made in a 2-acre, stock-proof exclosure in the cheatgrass type south of Boise, Idaho, during the spring and summer of 1957. Measurements of plant height of cheatgrass and two associated perennials, Poa secunda and Sitanion hystrix, were recorded throughout the active growing period. Table 7 summarizes differences in growth rate for these three species. Poa and Sitanion were taller than cheatgrass at all growth stages.

Table 7.--Plant height, in millimeters, of three grasses in the cheatgrass type, and percentage of soil-moisture in the surface 6 inches, in the spring of 1957 near Boise, Idaho

Date	Height			Soil moisture	
	Cheatgrass	Poa	Sitanion	Cheatgrass	Annual forbs
	mm.	mm.	mm.	Percent	Percent
4/10	38	78	216	28	--
4/18	50	81	247	25	17
4/29	76	--	277	19	12
5/6	123	245	296	17	14
5/17	223	283	315	21	11
6/14	--	--	--	9	7
7/24	--	--	--	4	4

The earliest forbs to flower were Lithophragma bulbifera, Lepidium perfoliatum, and Draba verna (April 9). Poa was in full head on April 18, 10 days earlier than cheatgrass and a month earlier than Sitanion. Poa reached

anthesis later than cheatgrass, however, because they both produced flowers at about the same time, between May 6 and May 17. Several forbs also flowered at this time: Sisymbrium altissimum, Amsinckia retrorsa, Zigadenus sp., and Allium sp.

Soil moisture samples were taken at this site from two areas quite different in their ground cover. One area supported a dense stand of cheatgrass and the other a sparse stand of annual forbs--mostly Gayophytum and Draba--with large bare spaces between plants. The soil was a friable, silty clay loam with a fair amount of organic matter in the top 6 inches.

The consistently lower soil moisture in the top 6 inches on the annual forb area indicates that evaporation is probably much more important than transpiration in moisture loss from this level. The cheatgrass area with its protective cover of litter maintained a higher soil-moisture content throughout the period of observation even though its transpiration potential was much greater. Drying of cheatgrass was associated with the marked decline in soil moisture between mid-May and mid-June, but the annual forbs remained green well into the summer, evidently utilizing soil moisture at greater depths.

SEASON OF GRAZING SPRING-FALL RANGE BY SHEEP

It has been shown over a 25-year period that spring grazing by sheep reduces the proportions of grasses and forbs on southern Idaho sagebrush-grass range.[9/] Under fall grazing at heavy intensity the herbaceous components of the vegetation were maintained, and it was believed that these tended to increase at the expense of shrubs.

In these grazing treatments two 80-acre range pastures were used. Pasture 1 was grazed heavily in the fall at the average rate of 42.6 sheep days per acre. Pasture 2 was grazed in the spring at the average rate of 19.2 sheep days per acre, and again in the fall at 10.0 sheep days per acre. In 1950 a north-south cross fence was constructed and grazing treatments were reversed in half of each of the two pastures. The eastern halves, labeled 1a and 2a, were grazed in fall and spring, respectively, much as they had been in the past. Pasture 1b, the western counterpart of 1a, was grazed in the spring; 2b, the western counterpart of 2a, was grazed in the fall. The grazing treatments were modified so that each pasture was grazed only in the spring at 40 sheep days per acre, or only in the fall at 60 sheep days per acre.

In 1950 and in 1957 the pastures were not grazed. Permanent plots were inventoried in each of these summers by the weight-estimate method. To facilitate summary comparison, the vegetation is divided into three classes--grasses, forbs, and shrubs--and results are expressed in terms of percent composition (table 8).

9/ Mueggler, Walter F. Effects of spring-fall grazing by sheep on vegetation of the Upper Snake River Plains. Jour. Range Mangt. 3: 308-315. 1950.

Table 8.--Composition of herbage in spring- and fall-grazed range pastures, 1950 and 1957, in percent of total herbage produced

Pasture	Season grazed	Sheep days per acre	Grasses 1950	Grasses 1957	Forbs 1950	Forbs 1957	Shrubs 1950	Shrubs 1957
			Percent		Percent		Percent	
1a	Fall	60	31	48	34	20	35	32
2a	Spring	40	34	28	11	6	55	66
2b	Fall	60	30	54	11	8	59	38
1b	Spring	40	26	28	42	16	32	56

In terms of absolute production, about the same weight of shrubs was produced on the two pastures in 1950, but only two-thirds the weight of grasses and one-fifth the weight of forbs on the spring-grazed (2a) as compared with the fall-grazed (1a) pasture. Continuation of the contrasting treatments emphasized the differences that had been observed during the previous 25 years: spring grazing penalized grasses and forbs and benefited shrubs; fall grazing had the opposite effect.

The reversed treatments, 2b and 1b, supply confirming evidence. Under spring grazing in 1b, forbs declined from 42 to 16 percent of the total, while shrubs increased from 32 to 56 percent. Under fall grazing (2b) the proportion of grasses increased but the proportion of shrubs declined. In light of their general decline, the forbs do not appear to have been affected adversely by this treatment.

These results support the conclusion that fall grazing by sheep can be a method of improving sagebrush-grass range. Such management may reduce sagebrush gradually over a period of years without the expense or risks of spraying, burning, or mechanical eradication. Furthermore, to achieve range improvement in this way, current forage production need not be completely sacrificed on areas that are rested in spring.

CRESTED WHEATGRASS UNDER BRUSH AND IN THE OPEN

The invasion of sagebrush (*Artemisia tridentata*) and rabbitbrush (*Chrysothamnus nauseosus*) into well-established crested wheatgrass stands (both *Agropyron cristatum* and *A. desertorum*) has been recognized as reducing the grazing capacity for livestock. On the other hand, grass growing under mature rabbitbrush, and under sagebrush to some extent, may be more vigorous than elsewhere. Weights of grass underneath both shrubs were obtained from caged plots at Benmore in 1957, along with weights from comparable caged plots in the open.

Prior to caging, April 16, two comparable brush plants of each species were selected in each of 24 experimental pastures. One of the two plants was then removed at random. The other brush plant was removed 3 months later when grass weights were measured on all plots, each 9.6 sq. ft. in area. Grass weights away from brush were obtained from two randomly selected caged plots that had been grazed in prior years.

Under sagebrush grass yields are slightly lower than on the brush-free plots (table 9). Seed stalks are also less numerous. These facts suggest that sagebrush competes rather strongly with crested wheatgrass. On the other hand, since grass yields and numbers of seed stalks are markedly greater under rabbitbrush than in the open, it would appear that rabbitbrush does not compete strongly with the grass. The beneficial effects of induced snow drifting in winter, and of reduced insolation and evaporation during the growing season, evidently outweigh the adverse effects of competition of rabbitbrush to a much greater extent than with sagebrush.

Table 9.--Production of crested wheatgrass in mid-July on 9.6 sq. ft. plots with and without brush[1/]

	Dry-weight yield	Seed stalks
	Gm.	No.
No brush	96.8	213
Sagebrush		
Removed April 16	84.2	130
Removed July 16	70.5	107
Rabbitbrush		
Removed April 16	161.8	308
Removed July 16	155.3	261

1/ To convert grams per plot to pounds per acre, remove the decimal point.

Another measure of competitive (and shading) effect is shown by the differences in production resulting from removal of shrubs early in spring (April 16) and removal at the end of active herbaceous growth (July 16). Numbers of seed stalks are increased about 20 percent by early removal of both brush species. The increase in yield from removing sagebrush early is also nearly 20 percent, but the increase from removing rabbitbrush is less than 5 percent.

HALOGETON ON DESERT-SHRUB RANGE

In 1952 halogeton was found in the bottom of Pine Valley both outside and inside the Desert Experimental Range. Plants were small and occurred sparsely inside the experimental range over approximately 8 acres along the southeastern side of the playa in scattered stands of Kochia vestita, Sarcobatus vermiculatus, Atriplex confertifolia, and Salsola kali tenuifolia. By 1953 the infestation had spread 2 to 3 miles across the playa, and seedlings were found in the vegetation along its border.

In June 1954, four areas in the Eurotia lanata and Atriplex confertifolia types on the experimental range were seeded to halogeton. On each area two 8 x 8 ft. plots were planted. On one plot native vegetation was removed before planting, but on the other, halogeton seed was raked in among the native plants. All plots produced halogeton plants in 1954, but plants were small because of drought; they averaged only 5 to 6 inches in height. Plants per plot varied from 8 to 23. In 1955, also a year of low rainfall, halogeton was found on only three of the four areas. After 4 years scattered halogeton plants are found within a 1/4-mile to 1/2-mile radius, primarily to the leeward and downhill, from the planting sites.

Halogeton is now well distributed over the desert outside the experimental range, with heavy infestations along the east and west boundaries. Inside the experimental range new spots are found each year primarily along roadways, on flood plains, and in one or two dry washes. Scattered halogeton plants on protected or moderately grazed areas are usually associated with rodent diggings or adjacent heavy infestations.

DROUGHT AND WINTERFAT MORTALITY

Low rainfall at the Desert Experimental Range during the past 9 years has resulted in low forage production and heavy mortality of many of the native forage plants on both grazed and ungrazed areas. Outside and inside an exclosure in Pine Valley mortality averages 19.0 and 15.6 percent, respectively (table 10). Mortality on the grazed area may be higher than indicated because trampling tends to destroy the dead plants.

Table 10.--Number, cover, height, and mortality of winterfat plants on heavily grazed and ungrazed areas, Pine Valley exclosure, 1957

	Ungrazed area	Heavily grazed area
Plants per 100 sq. ft. (no.)	45	49
Average size of plant (sq. in.)	18.7	5.1
Plant cover (percent)	5.8	1.7
Plant height (inches)	7.6	5.5
Mortality (percent)	15.6	19.0

Although total plant numbers are about equal, the winterfat plants are smaller and less vigorous on the heavily grazed than on the ungrazed range. In consequence, the stunted plants on the heavily grazed range provide less than one-third the cover of the plants on the ungrazed range.

BIG-GAME WINTER RANGE REVEGETATION

Mouse depredations on planted bitterbrush seed seriously limited the success of early seedings. With the cooperation of the Denver Wildlife Research Laboratory of the U. S. Fish and Wildlife Service, field tests were begun in southwestern Idaho in 1953 of seed treated with compounds intended either to repel or kill mice.

Tetramine (tetramethylene disulpho tetramine) proved to be a reliable seed protectant, but it was withdrawn from the market. Tests made in 1956 showed endrin, a commercially available insecticide, to be promising. It was tested again in 1957, separately and in combination with the fungicides arasan, copper omadine, and zinc omadine (fig. 4). Endrin alone appears to be somewhat inferior to tetramine as a protectant; this is in agreement with 1956 findings. The addition of any of the fungicides, particularly the omadines, resulted in much better protection from rodents than that provided by endrin alone and as good protection as that provided by tetramine.

Figure 4 shows clearly that seedling emergence is inversely related to rodent disturbance. There were on the average 1.7 seedlings per successful seed spot from untreated seed, but between 3.3 and 4.3 seedlings per spot from the five kinds of seed treatment. Both field and laboratory germination trials show no adverse effect due to treatment; in fact, they suggest that the addition of fungicides tends to raise germination rates.

Gibberellic Acid and Bitterbrush

Gibberellic acid was applied to field-sown bitterbrush in southwestern Idaho to determine whether it would improve growth of seedlings. If top growth can be accelerated, the plants may be better able to withstand browsing pressure; and if root growth can be accelerated, the seedling roots may be able to keep ahead of soil-moisture recession during the dry summer season.

Starting in mid-April, gibberellic acid in concentrations of 0, 10, and 100 p.p.m. was applied to three series of bitterbrush seedlings, a third of each series receiving one application at each concentration, and successive thirds receiving two and three applications at 10-day intervals. Periodic measurements showed that, regardless of the number of applications, there were differences in seedling height due to the concentrations of acid they received. These differences narrowed as the season progressed and had no practical significance by the end of August. Gibberellic acid appeared to have no significant influence on development of roots.

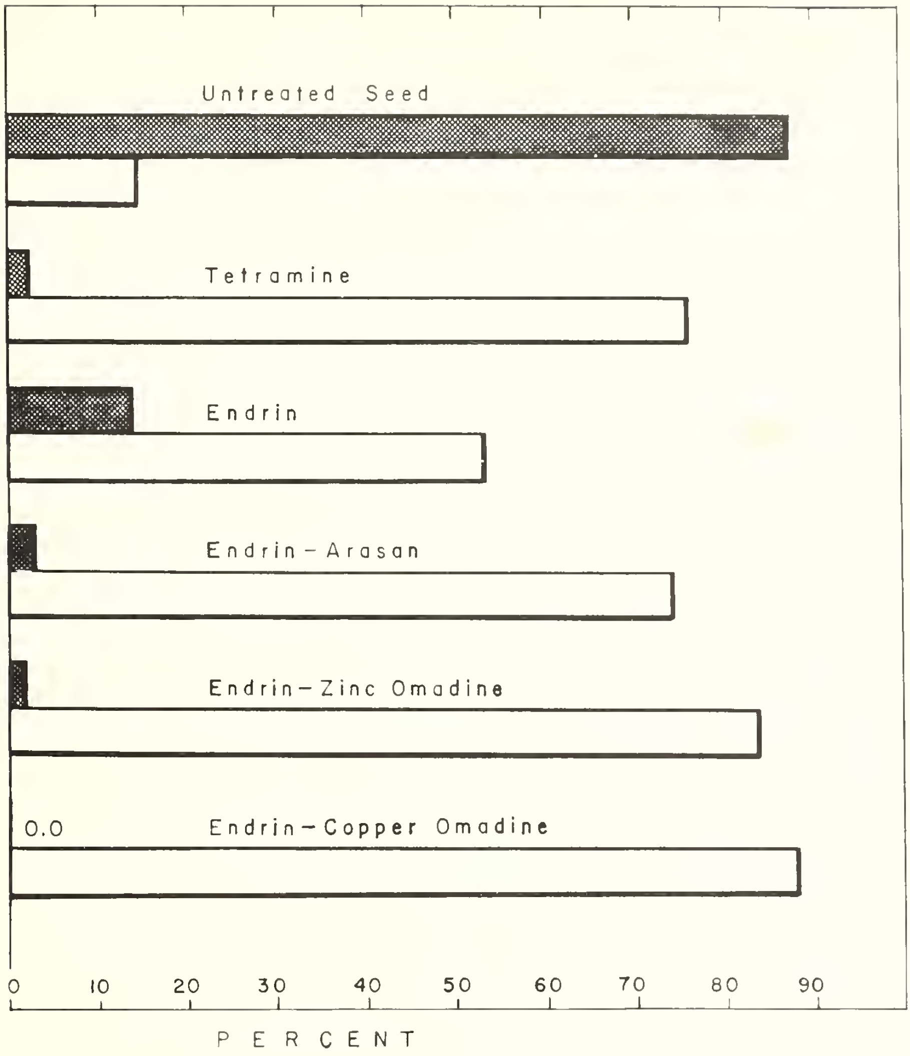


Figure 4.--Percentage of bitterbrush seed spots disturbed by mice (black bars) and percentage of seed spots in which seedlings emerged (white bars) as affected by seed protectants and fungicides.

Seedling Transplants

The transplant technique, whether with nursery stock or with seedlings, is most useful on sites where it is especially difficult to establish plants by direct seeding. Any transplant method is necessarily more expensive than direct seeding, but on some severe sites transplanting may be the only means of getting initial establishment of desirable shrubs. In first trials in central

Utah, seedling transplants 6 to 8 weeks old grown in coffee cans (see below), and from these planted directly into the field in holes made with a pulaski, appear to be as successful as 1- and 2-year-old nursery stock. Seedling transplants have the advantage of being less costly than nursery stock, and survival is essentially as good.

Shrub Utilization

Comparative utilization by deer of artificially planted shrubs 8 to 10 years old on two sites in the mountain-brush zone in central Utah is shown in percentages in the following tabulation. One site is a southerly exposure where deer naturally concentrate in winter; the other is a flat where they are less inclined to graze. Snow on the southerly exposure seldom exceeds a few inches in depth, and frequently melts off for extended periods; on the flat the snow may accumulate to a depth of 3 feet. Observations were made during the winter of 1956-57.

	Southerly slope	Flat
Fourwing saltbush (*Atriplex canescens*)	85	75
Curlleaf mountain-mahogany (*Cercocarpus ledifolius*)	80	75
Stansbury cliffrose (*Cowania stansburiana*)	85	80
Antelope bitterbrush (*Purshia tridentata*)	85	80
True mountain-mahogany (*Cercocarpus montanus*)	80	40
Winterfat (*Eurotia lanata*)	80	30
Blueberry elder (*Sambucus glauca*)	75	10
Big sagebrush (*Artemisia tridentata*)	50	30
Rubber rabbitbrush (*Chrysothamnus nauseosus*)	50	30
Gambel oak (*Quercus gambelii*)	40	15
Dunebroom (*Parryella filifolia*)	15	T
Mountain snowberry (*Symphoricarpos oreophilus*)	10	5

Utilization of the four most preferred species--fourwing saltbush, curlleaf mountain-mahogany, cliffrose, and bitterbrush--was only slightly greater on the southerly site than on the flat, despite the preference of deer for this site. This confirms the observation made on native range that deer seek out highly palatable shrubs regardless of site, if they can get to them.

Seedlings of Palmer penstemon, big sagebrush, and desert almond.

Winterfat, sagebrush, rabbitbrush, and elder were heavily utilized on the southerly slope but only moderately on the flat. Parryella and snowberry were utilized little, even on the concentration area.

These results suggest that deer may be manipulated to some extent by planting shrubs of differing palatability. Palatable shrubs like bitterbrush, curlleaf mahogany, and fourwing saltbush can be used to induce deer to flats and north slopes in order to relieve concentration areas. Moderately palatable shrubs like sagebrush and rabbitbrush can be planted on concentration areas: these shrubs provide considerable forage, and their growth habit and ability to reproduce abundantly provide a better ground cover than that provided by more palatable and less aggressive shrubs.

WATERSHED MANAGEMENT RESEARCH

The territory served by the Intermountain station is characterized by extremely varied climate, land forms, and land uses at differing intensities. This diversity poses a severe challenge to research in its task of providing guides and basic information on watershed management. The one reference base is that land management in any form must preserve watershed integrity. Hence the station's program in research on watershed management is concerned with restoration of impaired watersheds, maintenance of watersheds in good condition, and improvement of water yields.

History of land use in much of the nonforested Intermountain area is principally a story of intense grazing accompanied occasionally by rampant fires. These abuses of the plant cover resulted in various degrees of depletion and in many areas resulted in serious land deterioration that will require costly restoration measures.

In the territory of the station's activities the problem of soil stability is critical. Probably in no other section of America is the mountain-valley relationship so characteristic, so vital, and yet sometimes so precarious. Upon this relationship the well-being of much of the Intermountain West depends--water from the mountains for life in the valleys. This relationship appears dramatically in the following photo. Means to alleviate problems affecting this mountain-valley relationship are being sought through the station's research programs.

Within the station territory, annual precipitation ranges from less than 10 inches to about 60 inches. Seasonal distribution is variable, but the greatest portion occurs during the winter months. Important water-yielding areas coincide closely with those having high snowfall. Rapid snow melting, sometimes accompanied by rain, causes high peak flows in the spring that are followed by deficient streamflow when seasonal need for water is greatest. These conditions accentuate the need for water yield improvement measures.

RESTORATION OF DEPLETED WATERSHEDS

Subalpine-Herbaceous Range

Studies of techniques for restoration of subalpine-herbaceous range have had priority at the Great Basin Research Center ever since its establishment in 1912. Studies covering more than 40 years' duration indicate clearly that herbaceous vegetation effectively controls storm runoff and sediment production. However, following severe site depletion and soil erosion, herbaceous vegetation achieves this control very slowly.

The A and B Watersheds afford interesting comparisons of runoff and erosion under various treatments affecting plant cover density. Watershed A has been permitted to revegetate naturally since about 1920, with little or

This Utah town and adjacent farmland illustrate the "mountain-valley" relationship characteristic of this region. Both culinary and irrigation water are derived from high-elevation precipitation, chiefly snow.

no grazing. Ground cover density, after showing an initial improvement the first few years, has changed little during the past 25 years; but changes in cover composition are evident. The watershed continues to produce runoff and sediment: last year sediment production of 5.16 cu. ft. per acre was measured.

Watershed B was subjected to moderate grazing for several years prior to World War II; but after the war it was grazed heavily and became severely depleted. In 1952, intensive treatment was applied to restore the plant cover. This treatment resulted in highly significant improvement in grass cover and a major reduction in broad-leaved forbs. Sediment production (only 0.11 cu. ft. per acre in 1957) is scarcely measurable. Ground cover of plants and litter on Watershed B is now more uniformly distributed than on A, and is comparable to its previous density, which it supported in the late 1940's. Not only have runoff and erosion been greatly reduced, but outstanding improvement in forage quality resulted from the contour trenching and reseeding.

Effects of Plant Cover on Runoff and Erosion

In 1936, 16 plots were installed in the upper portion of the Parrish Watershed (Davis County Experimental Watershed) for measuring surface runoff and soil erosion. Some plots occupied relatively undepleted sites; others were on depleted areas where signs of erosion indicated them to be sources of flood runoff. After 11 years of records were obtained, some of the sparsely covered flood-source plots were seeded to grass; on some others the plant cover was allowed to increase naturally; and some plots were denuded completely. The objectives were to establish a relationship between type of plant cover and overland flow and erosion; to determine the minimum amount of vegetal cover necessary to control runoff and erosion; and to show that depleted flood-source areas can be restored to a nonflood-producing condition.

Plot 7 was one of those denuded completely in 1947. All vegetation and litter were removed or destroyed by cutting, burning, and raking. Records of summer storms, overland flow, and sediment production for the 11-year periods before and after treatment are summarized in table 11.

Table 11.--Number of storms, amounts of overland flow, and sediment eroded from the 0.1-acre Parrish Plot No. 7, 1936-1957

Period	Summer rainfall		Overland flow		Sediment eroded		
	Total storms	Total ppt.	Total storms	Amount	Total storms	Amount	Area
	No.	In.	No.	Cu.ft/A	No.	Cu.ft/A	In.
Before denudation (1936-1946)	130	34.08	23	242.7	0	0	0
After denudation (1947-1957)	161	42.23	49	16,554.9	34	2,426.7	0.67
Total	291	76.31	72	16,797.6	34	2,426.7	0.67

During these 22 summer seasons, 291 storms occurred--72 producing runoff and 34 causing both runoff and erosion. No detectable amounts of sediment were produced by the 23 storms causing runoff prior to denudation. Following treatment, 34 of the 49 runoff-producing storms also caused erosion, and the amount of overland flow increased 33 times that occurring the first 11 years. Erosion occurred at the average rate of nearly 0.02 inch per sediment-producing storm totaling an average loss of 0.67 inch. Erosion has not been uniform over the plot because of rilling; nevertheless it is severe.

The data in table 11 also show that before treatment only about 17 percent of the summer storms caused runoff. After treatment, 30 percent of the storms did.

Correlation analyses show highly significant relationships between the independent variables: total summer rainfall, total individual storm precipitation, and maximum 5-minute rainfall intensity and the dependent variable: overland flow. Sediment production is also significantly related to maximum storm intensity and total storm precipitation.

IMPROVEMENT OF WATER QUALITY

Control of Sediment from Logging Roads

Keeping sediment out of streams on lands being logged is an acute problem. As construction disturbance is extended into unstable, steeper, and less accessible lands, the severity of this problem increases. Encouraging progress was made this year in developing guides for better road location and construction.

Four variables were found to be highly correlated with the distance that sediment flows downslope from newly constructed logging roads. An equation expressing their relationship provides a means of estimating the distance or width of buffer strip required to dissipate sediment movement between roads and streams. A field guide for locating roads so as to keep sediment production at a minimum is being prepared for publication. This approach to a road location and treatment guide provides considerable flexibility in application because several of the equation variables are amenable to control by the road locators.

Logging Disturbance and Sediment Production

Intensified logging operations in areas having unstable soils result in soil disturbance and destruction of plant cover. These result chiefly from ground plowing by skidding logs, churning of the soil by heavy tractors, and construction of numerous haul roads. Erosion and sediment deposition in streams follow inevitably. Yet under a multiple-use management program certain of these areas stocked with mature stands of timber warrant harvesting. How to log these areas and maintain the integrity of the watersheds is being studied on the Boise Basin Experimental Forest.

Watersheds on the 20 logging compartments comprising this study vary in size from 5 to 10 acres up to 35 to 50 acres. Sixteen watersheds have been logged, and the other four have been retained as unlogged controls. Logging operations were controlled stringently; cross ditches were carefully constructed; skidtrails were plugged and ditched wherever necessary; and roads were located with extreme care in consonance with topographic limitations. Sediment basins were constructed in each compartment in 1954 and the stilling ponds were referenced and gridded to establish permanent sediment measuring points.

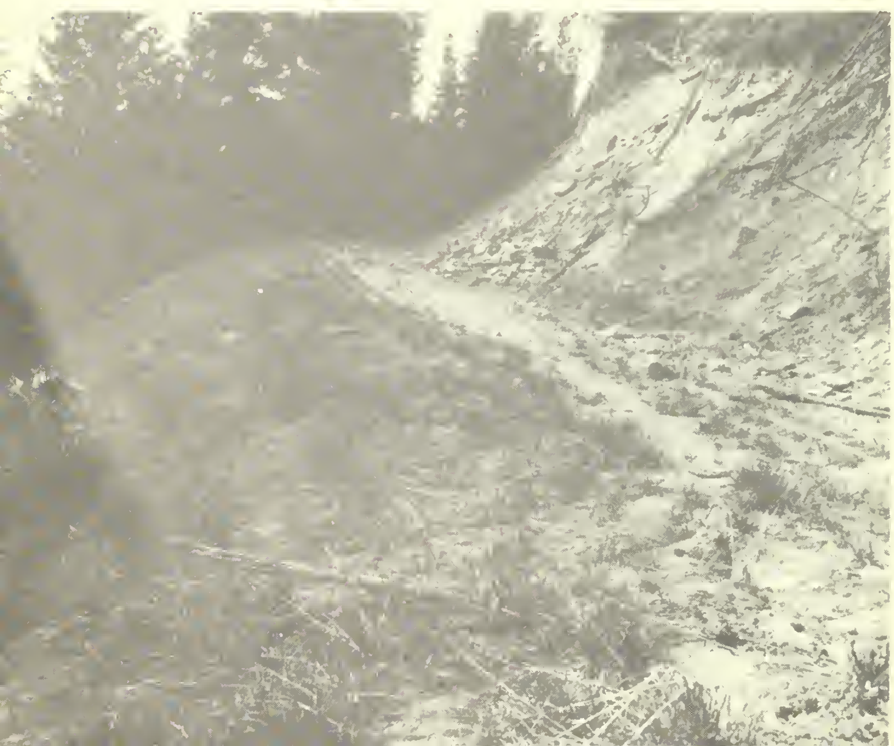
The areal extent of logging disturbance ranged from 3.6 to 9.1 percent of each compartment. Haul roads constituted 58 percent of the disturbed area, skidtrails 29 percent, and landings 13 percent. Only five of the watersheds (four logged and one unlogged control) are actively producing sediment. Average sediment production per year on the four logged compartments varies from 1.7 to 29.5 tons per square mile; on the control area production is 3.1 tons. The compartment that produces most sediment has a road very near the stream bottom. Reasonable discretion in road location, coupled with adequate safeguards in skidtrail stabilizing treatments, permits logging operations consistent with good watershed management.

Repairing Construction Disturbance

Studies have been undertaken in the loose granitic soils of southwestern Idaho to determine how to reduce soil erosion from logging haul roads and skidtrails to the minimum. Tests of mechanical structures include cross ditches spaced at varying intervals, log bars, and slash plugs in skidtrails on hillsides and ravines. Evaluation of these structures is under way. Answers to such questions as whether skidtrail control structures are properly placed, which type of structure is most efficient, and whether establishment of grass cover aids in erosion control are being sought.

Another study tests different methods of seedbed treatment on the establishment of grass cover on raw surfaces of haul roads. Treatments consist of broadcast seeding, seeding and harrowing, seeding followed by scarification, and scarification followed by seeding. Plots under treatment total 144; of these, 64 received a thin mulch of wood chips.

Observations after one year show that: (1) haul roads can be revegetated by seeding (see photo below); (2) the percentage of plant cover established on northwest aspects exceeds that on southwest aspects; (3) surface mulching



Section of a logging haul road reseeded to stabilize raw soil. A good stand of grass aids in reducing road surface erosion. Raw bank cuts present another problem of stabilization.

with wood chips is of little or no benefit towards plant cover establishment; and (4) scarification scarcely improves establishment of plant cover. This study is being continued to learn the most feasible postlogging treatment for haul roads.

Soil Density-Runoff Relations

Past tests in central and northern Utah and southern Idaho show that for common range conditions 65 percent or more of total ground cover protects effectively against soil loss and reduces materially and sometimes eliminates water loss from surface runoff. Thus, the generalization that runoff varies inversely with the amount of total ground cover is valid.

Further examination of data from a study in central Utah showed that the relationship of runoff to ground cover was also affected by the bulk density of the soil. Throughout the range of ground cover densities, runoff increased uniformly with increased bulk density (figure 5). Under an applied rainfall

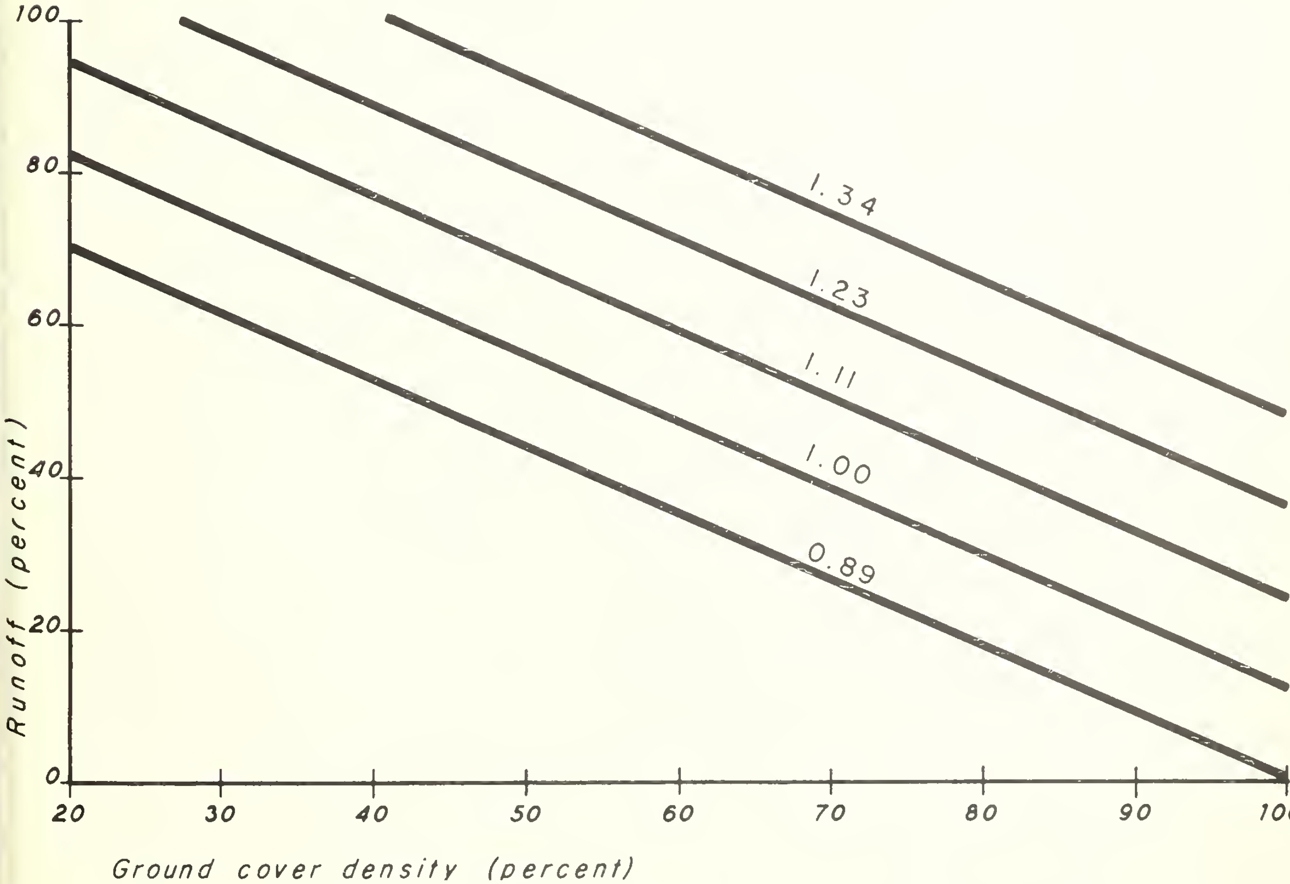


Figure 5.--Runoff from 3 inches of rainfall in relation to ground cover as influenced by bulk density of the surface soil. Numbers on each curve are bulk density values.

of 3 inches, a ground cover of 43 percent sufficed to limit runoff to 50 percent on a porous soil having a bulk density of 0.89. A virtually complete ground cover would be required to obtain the same degree of runoff control on sites having a soil bulk density of 1.34. Excessive trampling by livestock compacts soil, and the implications of compaction are apparent in the following graph.

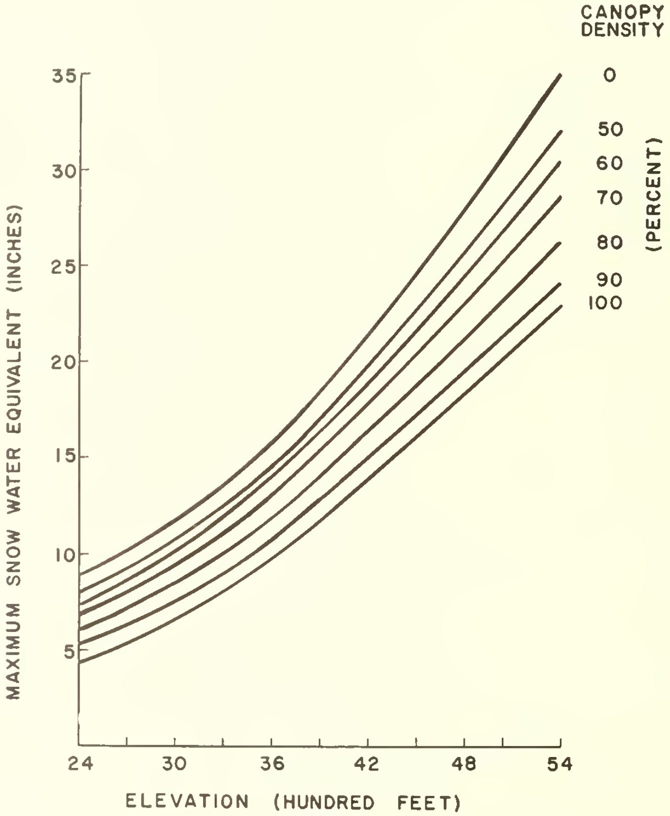


Figure 6.--Maximum snow water equivalent accumulated under different forest canopy densities at different elevations.

Snow Accumulation in White Pine Forests

Winter snowpack in white pine forests of northern Idaho is a principal source of streamflow for several major tributaries of the Columbia River. Frequently, rapid melting of this snowpack, often accompanied by rain, causes spring flood peaks along these tributaries and aggravates peak discharge stages on the Columbia River itself. Because these forests are subject to harvest, the problem of harvesting them without increasing the flood hazard is posed.

Clues to a solution for this problem were sought in a study of the relationship of snow accumulation to elevation, aspect, and forest cover density. Snow accumulation data were obtained on the Priest River Experimental Forest in northern Idaho during 1949-52 as a part of the Flood Survey division activity. Forty-four snow courses, representing 202 snow-measuring points in the open and 290 points in timbered areas, were measured in those years.

The basic data were stratified by elevational zones, by canopy density classes, and by aspects. Curvilinear regressions developed within separate strata resulted in the series of curves shown in figure 6. Where the canopy density is zero (which corresponds to a clean-cut forest condition) maximum water equivalent exceeds that of increasing canopy densities at all elevations from 2,400 to 5,400 feet. At the maximum elevation of 5,400 feet, the effect of a complete canopy is to intercept almost 12 inches of water. The interception effect of canopy is less at lower elevations, yet the difference between open and timbered areas is significant. Throughout the range of canopy densities, snowpack water equivalent increases with increases in elevation.

Changes from north to south aspects show a significant reduction in snowpack at all elevations. At 5,400-foot elevation, for example, an average of 11.9 inches less water accumulated on south aspects than on north aspects--31.7 versus 43.6 inches. This difference by aspects is due primarily to a longer period of melting on south exposures with consequent loss of water; whereas on north exposures snow accumulation usually continues until spring melting period.

These results are important in watershed management. They enable us to evaluate quantitatively the influences of elevation, cover, and aspect. They also point to other considerations. If clear-cutting permits accumulating an additional foot of water in the snowpack, what will happen to streamflow peaks? Can strip clear-cutting be used to accumulate more snow, and will strip-shading retard melting to avoid aggravating peak flows? This study suggests important and far-reaching effects of forest management practices on manipulation of snowpack water.

Water Yield Improvement Through Snowpack Manipulation

Improvement of water yields in respect to quantity, quality, or timeliness of flow is one major objective of watershed management research. Too often, and unfortunately, the only thought given to water yield improvement is that of producing "more water." This increase, of course, is highly desirable, but not at the expense of increased sedimentation or damaging peak flows of flood magnitude. Research in water yield improvement with respect to both quantity and quality is being accelerated.

Precipitation in 1956-57 in Ephraim Canyon, central Utah, almost equaled the record high precipitation in 1951-52, and exceeded by several inches the 20- to 34-year average. Streamflow of Ephraim Creek in June 1957 was the highest ever recorded--14,092 acre feet. The previous high was 10,635 acre feet in 1942 and the past 16-year average 6,061 acre feet.

To regulate timeliness of streamflow by snowpack manipulation to modify this early season discharge has utmost importance. Early tests showed that fences effectively induce snowdrifting that delays snowmelt for about 2 weeks on high-elevation, herbaceous ranges. Similar effects of induced snowdrifting behind such obstacles as clumps of trees can be observed each year (see following photo.) If peak streamflow, such as was experienced in June, could be reduced and runoff strengthened in later months enormous benefits would accrue. To explore further the possibility of improving timeliness of flow, a new snow manipulation study was begun this year. The study is divided into three phases: (1) tests of fence heights, spacing, and orientation with respect to wind direction and topography; (2) treatment of a small calibrated watershed to determine the efficacy of fence structures; and (3) reforestation of watersheds in strips to achieve drifting by natural vegetation. This study will require several successive seasons. Results will be reported periodically.

Snowdrift formed behind clump of trees on high elevation range, central Utah. The drift extended about 50 feet from the trees. Its maximum depth was 6 feet, and its width 25 feet at base in early June. Note typical mature drift shape.

Progress of Type Conversion Plans

Evapotranspiration losses of aspen stands exceed those of brush and herbaceous types of vegetation on high elevational areas in northern Utah. Interest in vegetation type conversion to improve water yields is mounting. Two projects pointed toward solving this problem are under way: One is a study of summer water use by aspen and mountain brush; the other involves calibration of paired aspen-covered watersheds. Five years' streamflow records reveal a high correlation ($r = 0.994$) between the flows of the two streams. When this relationship is determined to be sufficiently stable to permit prediction of streamflow of one from that of the other, conversion of cover on one watershed will be made and its effects evaluated.

Research Program Starts in Nevada

Steps have been taken toward starting research on watershed problems in western Nevada and parts of eastern California. These include transfer of a watershed management specialist to Reno, reactivation of the Nevada Research Center, and the commencement of a problem analysis for that area.

How to reduce flood discharges and increase timber and forage productivity of the Jeffrey pine and brushlands on the east slopes of the Sierra Nevada appear to be high priority research problems. In recent years, winter floods caused by rapid melting of deep snow and summer floods from torrential rains have increased in frequency and destructiveness. Flood damage in the Reno area alone now averages nearly $1 million per year. Flood runoff originates, in part, on lands below which major structural control is not feasible. The flood-source areas have been drastically depleted of plant cover by past fires, timber clear-cutting, and overgrazing. Now these lands contribute only a fraction of their potential value to the regional economy and appear to have lost much of their storage capacity essential to flood prevention. Research must develop feasible restoration techniques for rehabilitating these important watersheds.

PUBLICATIONS

A. Departmental publications

LEAPHART, CHARLES D., OTIS L. COPELAND, JR., and DONALD P. GRAHAM. Pole blight of western white pine. U. S. Dept. Agr. Forest Pest Leaflet 16. 4 pp., illus.

An up-to-date account of pole blight symptoms, distribution, and damage. Discusses research to determine the cause of this disease.

WASSER, C. H., LINCOLN ELLISON, and R. E. WAGNER. Soil management on ranges. U. S. Dept. Agr. Yearbook 1957: 633-642.

Thumbnail sketch of range-management objectives, ecological trends under grazing, grazing management practices, and methods of artificial range improvement.

WOODS, FRANK W., OTIS L. COPELAND, JR., and CARL E. OSTROM. Soil management for forest trees. U. S. Dept. Agr. Yearbook 1957: 710-715.

Describes management practices consisting chiefly of indirect measures. Discusses problems of water excesses and deficiencies, and offers recommendations. Reviews forest disease, soil relationships, and fertility requirements of trees.

B. Publications in scientific and professional journals, etc.

BARROWS, J. S. Project Skyfire--A progress report on lightning fire research. 48th Ann. West. Forestry Conf. Proc., West. Forestry and Conserv. Asso., pp. 54-56.

Summarizes the lightning fire problem in western forests and discusses the organization of the Project Skyfire research program. Presents preliminary results of cloud-seeding research during the 1957 fire season.

BARROWS, J. S., JOHN H. DIETERICH, CLYDE A. O'DELL, CHARLES H. KAEHN, U. S. Forest Service; DONALD M. FUQUAY, VINCENT J. SCHAEFER, and PAUL B. MacCREADY, JR., The Munitalp Foundation, Inc., DeVER COLSON, U. S. Weather Bureau; H. J. WELLS, Advisory Committee on Weather Control. Project Skyfire, reprinted from Final Report of Advisory Committee on Weather Control. U. S. Govt. Printing Off., Washington, D. C., pp. 105-125.

Discusses preliminary results of all phases of Project Skyfire. Five tentative conclusions are presented on cloud modification and artificial nuclei studies.

COPELAND, OTIS L., JR. Ecological considerations of the pole blight disease. Fourth Internatl. West. Disease Work Conf. Proc., pp. 49-55.

Reviews the occurrence of western white pine pole blight and damage caused by this disease. Also reviews research conducted to determine the cause of pole blight. Dicusses climatic, edaphic, and biotic factors as possible contributing causes of the disease.

COPELAND, OTIS L., JR. A study of the influence of moisture and compaction on soil oxidation-reduction potentials. Soil Sci. Soc. Amer. Proc. 21(3): 269-271.

Soils receiving the optimum moisture-no compaction treatment maintained the highest state of oxidation during the test, while the saturated high-compaction series developed the lowest potentials. The positive poising capacity of the test soils is attributed to large quantities of hydrated iron oxides coupled with a paucity of active organic matter.

DODGE, HAROLD R. Defoliating insects in the northern Rocky Mountains in 1955. Northwest Sci. 31(1): 38-42, illus.

Describes the extent and severity of infestations of several insect pests of coniferous forests.

ELLISON, LINCOLN. Grazing standards in range management. New Zealand Grassland Assoc. Proc. of 18th Conf. Nov. 27-29, 1956: 136-147.

Judgment of range condition and trend rests upon two principles: prevention of accelerated erosion and use of the potential of the specific site as a standard. The evidence of process written on the range in the form of indicators must be our first and final authority; interpretation of these indicators must relate to the particular ecosystem with which we are dealing.

ELLISON, LINCOLN. Applications of ecology--concluding statement (in symposium on applications of ecology). Ecology 38(1): 63-64.

Comments upon preceding papers (on applications of ecology in forest, range, wildlife, and wild land soil management and in public health) in light of their contributions to ecological understanding, and upon the need for free interchange of ideas among subject-matter fields.

ELLISON, LINCOLN. A panel discussion of the place and functions of the division of range management in the Society of American Foresters: historical sketch. Jour. Forestry 55(4): 312-313.

The big problem--that of promoting coordinated wild land management--is still unsolved by existing professional societies. Although the formation of subject-matter divisions in the S.A.F. attempts this coordination, the author doubts whether the range division can contribute effectively to solution of the problem because few range men belong to the S.A.F.

FRISCHKNECHT, NEIL C., and ALVIN T. BLEAK. Encroachment of big sagebrush on seeded range in northeastern Nevada. Jour. Range Mangt. 10(4): 165-170.

Of the sagebrush present 10 years after treatment, about one-fifth was old plants that had survived eradication, three-fifths were plants that had become established at the time of seeding, and one-fifth was plants that had invaded after establishment of the crested wheatgrass--mostly in areas where grazing use had been heavy. Halogeton has recently invaded heavily grazed and barren spots.

FUQUAY, DONALD M., The Munitalp Foundation, Inc., and KONRAD BUETTNER, University of Washington. Laboratory investigation of some characteristics of the Eppley pyrheliometer. Amer. Geophys. Union Trans. 38(1): 38.

Laboratory investigations have confirmed field observations of inconsistent behavior of the Eppley pyranometer. Describes experiments and theories to explain ways to avoid the following errors: (1) Variable temperature coefficient; (2) variation of thermopile output with direction of gravity, and effect caused by internal air convection; (3) errors caused by radiation coming from the back side and being reflected by the glass cover; (4) errors from specular reflectivity of the black receiver ring and the resulting deviation of response from the cosine law.

GIBSON, ARCHIE L. Tests of bark penetrating insecticides to control the Douglas-fir beetle. Jour. Econ. Ent. 50(3): 266-268.

Reports the amount of Douglas-fir beetle brood mortality achieved by the application of several insectcides to bole sections of infested trees; describes formulations employed and the mode of application.

JOHNSON, PHILIP C. Report on insect enemies in (the northern) Rocky (Mountain) region. West. Conserv. Jour. 14(1).

Describes current insect infestations in the forests of the northern Rocky Mountains.

LEAPHART, CHARLES D., and OTIS L. COPELAND, JR. Root and soil relationships associated with the pole blight disease of western white pine. Soil Sci. Soc. Amer. Proc. 21(5): 551-554.

Shows the relationship between the rootlet condition of white pine pole stands affected by pole blight and two soil characteristics, effective soil depth and available moisture-holding capacity. Reviews factors affecting various root characteristics in healthy white pine stands ranging from 20 to 110 years old.

LYNCH, DONALD W. Simplified method of teaching use of compass. Fire Control Notes 18(2): 62-63.

Describes and illustrates a method of teaching use of the Forest Service compass, especially to groups of students at guard schools. This method employs a wooden model with the stationary "compass needle" oriented toward magnetic north and the body of the compass free to rotate beneath it.

MacCREADY, PAUL E., JR. The Munitalp Foundation, Inc. The Munitalp cloud theodolite. Amer. Met. Soc. Bul. 38(8): 460-464.

Describes various forms of the instrument and gives the method of determining cloud direction and velocity with the cloud theodolite. Discusses instrument errors.

NAGEL, R. H., DAVID McCOMB, and F. B. KNIGHT. The trap tree method for controlling the Engelmann spruce beetle in Colorado. Jour. Forestry 55(12): 894-898.

The natural preference of the beetle for breeding in freshly felled green trees has been used in field tests to develop a practical method of limiting or preventing attacks of the beetle in living trees. Freshly cut green trees deployed in strategic locations throughout the forest concentrate and absorb the resident beetle populations where they may be subsequently destroyed. Describes techniques and compares the beetle population densities in the felled "trap" trees and nearby living trees.

PLUMMER, A. PERRY, ROBERT L. JENSEN, and HOMER STAPLEY. Range revegetation. Utah Fish and Game Magazine 13(6): 8-9.

A progress report on the first 2 years' results of artificial shrub revegetation in central Utah: some promising species.

ROTH, ELMER R., and OTIS L. COPELAND, JR. Uptake of nitrogen and calcium by fertilized shortleaf pine. Jour. Forestry 55(4): 281-284.

Littleleaf-diseased trees that received nitrogen made pronounced recovery and contained normal amounts of nitrogen one year after treatment. Growth increases accompanied improvement of crown appearance. No improvement in disease symptoms resulted from applied calcium.

SCHAEFER, VINCENT J. The Munitalp Foundation, Inc. Atmospheric studies from a moving weather observatory. Amer. Met. Soc. Bul. 38(3): 124-129.

The moving weather observatory is described, and techniques for its operation are explained. The results of a mountain wind and temperature study are used to determine its value as a piece of mobile weather equipment.

SCHAEFER, VINCENT J. The Munitalp Foundation, Inc. The relationship of jet streams to forest wildfires. Jour. Forestry 55(6): 419.

Reports on the relationship between dry, gusty ground winds and the proximity of the high level jet stream. A case example is described where a forest wildfire was thought to be directly caused by a pivoting jet stream.

SQUILLACE, A. E. Variations in cone properties, seed yield, and seed weight in western white pine when pollination is controlled. Mont. State Univ., School of Forestry Bul. 5, 16 pp., illus.

Seeds borne on shoots in the upper and outer crown and on the south and west sides of individual trees tended to be heavier than those in opposing portions of the crown. Cones borne on the more fruitful shoots tended to be longer and contained heavier seeds than those on the less fruitful shoots. Average weight of seeds in individual cones was found to be directly related to cone length and scale size and inversely related to seed yield. Longer cones usually yielded more seed but yield was also affected by pollen parent. An apparent effect of pollen parent upon the shape of cone scales was also found.

STAGE, A. R. Some runoff characteristics of a small forested watershed in northern Idaho. Northwest Sci. 31(1): 14-27.

Sixteen years' records on Benton Creek show that two-thirds of each year's runoff occurred during April, May, and June. Average annual runoff from the Benton Creek Watershed is estimated to have been 11.2 inches for the period 1911-55. Evapotranspiration losses are estimated to have been 25.0 inches for the same period.

TACKLE, DAVID. Protection of ponderosa pine cones from cutting by the red squirrel. Jour. Forestry 55(6): 446-447.

Banding isolated ponderosa pine seed trees with a sheet of 18-inch-wide, smooth aluminum prevented red squirrels from climbing the trees and cutting cones and cone-bearing branches. Narrower bands were ineffective. Protected trees (trees with 20-inch bands) with branches 5.3 feet or more distant from the branches of adjacent unprotected (unbanded) trees did not experience cone or branch cutting by squirrels. Under normal conditions a 7- or 8-foot isolation should prevent jumping by squirrels from unbanded to banded trees, since under escape conditions, red squirrels have been observed to jump 7 feet horizontally and to span 10 feet in a downward diagonal drop.

U. S. DEPT. OF AGRICULTURE. Project Skyfire. Picture story 104, USDA, Office of Information, Washington, D. C.

Briefly describes the operational phases of the project and its attack on the basic lightning storm problem.

C. Processed reports

BASILE, JOSEPH V., and RALPH C. HOLMGREN. Artificial revegetation studies on depleted big-game winter ranges in Idaho. Job Completion Reports, Project W-111-R-3. Idaho Fish and Game Dept., 11 pp.

A comparison of five chemical formulations as protectants of sown bitterbrush seed against rodent depredation. Effects of deer on browse revegetation, and results of species adaptability tests are also given.

BASILE, JOSEPH V., and RALPH C. HOLMGREN. Seeding-depth trials with bitterbrush (*Purshia tridentata*) in Idaho. Research Paper 54, 10 pp., illus.

Describes tests over a 6-year period, under conditions suitable for machine and hand seeding of bitterbrush, to show relation of seeding depth and seed-group size to time and rate of seedling emergence, frost heaving, and survival.

BINGHAM, R. T., and A. E. SQUILLACE. Phenology and other features of the flowering of pines, with special reference to *Pinus monticola* Dougl. Research Paper 53, 26 pp., illus.

In western white pine the average date of first anthesis at high elevation was July 8, at low elevation June 27. Average period of pollen dissemination was 8½ days, ovulate flower receptivity 9½ days. Flowering was delayed approximately 5 days per 1,000 feet increase in elevation, and 6 days per degree F. departure of May and June temperature below normal. Individual trees were found to be consistently early or late in time of onset of flowering, and the sequence of flowering between localities was firmly fixed.

COLSON, DeVER. U. S. Weather Bureau. Thunderstorm analysis in the Northern Rocky Mountains. Research Paper 49, 13 pp., illus.

Describes methods used to survey cloud and thunderstorm conditions. Reviews three types of thunderstorms occurring in the northern Rocky Mountains, and presents data on several thunderstorm situations.

CURTIS, JAMES D., and DONALD W. LYNCH. Silvics of ponderosa pine. Misc. Pub. 12, 38 pp., illus.

A description of the silvics of the species based on available data through 1956. Includes dendrological features and mensurational characteristics considered pertinent to development and growth, from flowering stage and and germination of seed to the overmature tree.

DIVISION OF FOREST INSECT RESEARCH. Forest insect conditions in the Intermountain and northern Rocky Mountain States during 1956. Misc. Pub. 11, 6 pp.

Presents the results of cooperative forest insect surveys for 1956. Statements on the more important insects are included.

DODGE, HAROLD R., TOM T. TERRELL, and PHILIP C. JOHNSON. Entomological phases of the 1955 Montana spruce budworm control project. Misc. Pub. 9, 20 pp., illus. (Note: this reference did not appear in the 1956 annual report.)

Describes biological techniques and observations needed to assure successful control of the budworm on 372,652 acres of Douglas-fir forests in Montana during July 1955. Special reference is made to the progress of larval development needed to time the application of DDT aerial insecticide, to the insecticide formulation and its mode of application, to the physics of aircraft spraying, and to the method of determining the lethal effectiveness of the insecticide application.

FRISCHKNECHT, NEIL C. Effects of various grazing treatments on crested wheatgrass. Wash. State Col. Dept. Anim. Husb. Stockmen's Handb. 1956: 28.

Removal of 80 percent of the current year's growth of crested wheatgrass for eight consecutive years resulted in deterioration of the grass and increase of brush and other undesirable species. Sixty percent annual removal was considered more nearly proper to achieve maximum sustained forage and animal production.

FRISCHKNECHT, NEIL C. Managing crested wheatgrass for greatest cattle gains. Wash. State Col. Dept. Anim. Husb. Stockmen's Handb. 1956: 29-30.

Cattle gains under 12 grazing treatments are discussed. Intensity of grazing influenced daily animal gains and gain per acre more than system of grazing did.

FUQUAY, DONALD M., and H. J. WELLS. The Project Skyfire cloud-seeding generator. Research Paper 48, 17 pp., illus.

Describes two basic generator types and gives the reasons for developing a new generator. Summarizes calibration procedures and results.

FURNISS, MALCOLM M. Entomological aspects of the 1955 southern Idaho spruce budworm control project. Misc. Pub. 10, 29 pp., illus.

Describes procedures for gathering biological data necessary for determining spraying dates, checking spray deposit, and assessing mortality. Some problems attending spray operations are discussed and recommendations made for improvement in methods.

HUTCHISON, S. BLAIR. Market prospects for Mountain States timber. Research Paper 50, 31 pp., illus.

Analyzes the long-range prospects for increased utilization of the timber resources in the eight Mountain States. Attempts to interpret the national timber outlook described in the Forest Service's TIMBER RESOURCE REVIEW in terms of what it may offer as industrial opportunities for the Mountain States.

HUTCHISON, S. BLAIR, and JOHN H. WIKSTROM. Industrial opportunities in the headwater timber development unit. Research Paper 45, 70 pp., illus.

The Headwaters Timber Development Unit is a 5-million-acre area of commercial forest in southeastern Idaho, western Wyoming, and the northern edge of Utah. At present, relatively little use is being made of this timber. The report indicates the extent of industrial development possible from this resource and attempts to describe the type of development that would make fullest use of it.

KEMP, PAUL D. Regression coefficients for computing cubic-foot volume of Rocky Mountain trees. Research Paper 40, 12 pp.

Presents the regression coefficients used to adapt Forest Survey cubic-foot volume tables to the computation of volume by formula on IBM punch card machines. The regression coefficients vary by species and one-tenth d.b.h. classes.

KEMP, PAUL D. A procedure for converting conventional tree volume tables (cubic) to formulae (Part 1). Research Paper 43, 7 pp., illus.

Presents the basic procedures used to develop the regression coefficients presented in Research Paper 40.

LYNCH, DONALD W. How many trees should be log graded to determine sales realization value. Research Note 45, 6 pp.

An accurate sales realization value (sales price of manufactured lumber) for log graded timber sales can be determined by sample grading a portion of the trees. Standards for obtaining the sample for prescribed levels of accuracy and probability are presented in tables and equations.

LYNCH, DONALD W. Truck load sample scaling to adjust company scale. Research Note 48, 7 pp.

Describes a system of sample scaling that determines an adjustment factor to bring company scales (which are customarily 100 percent gross scales) to Forest Service net standards. Points out that an adjustment factor (to any desired degree of accuracy) can be determined with less scaling than is required to achieve an equally accurate average volume figure in conventional sample load scaling.

MIELKE, JAMES L. Aspen leaf blight in the Intermountain region. Research Note 42, 5 pp.

Contains information on distribution and hosts of the fungus, epidemiology, symptoms of the disease, and character of damage to aspen.

MIELKE, JAMES L. The Comandra blister rust in lodgepole pine. Research Note 46, 8 pp.

This rust fungus is now epidemic in many stands of lodgepole pine in the Intermountain region. Its distribution, hosts, life history, character of attack and damage to the pine, epidemiology, ecology of the alternate host, relation of rodents to the fungus on pines, and control are briefly discussed.

MIELKE, JAMES L. The yellow witches' broom of subalpine fir in the Intermountain region. Research Note 47, 5 pp.

Yellow witches' broom disease is epidemic on several areas in the Intermountain region. The range of the rust, its hosts, life history, description of the disease on subalpine fir, damage, epidemiology, ecology of the alternate hosts, and control are briefly discussed.

MOESSNER, KARL E. Preliminary aerial volume tables for conifer stands in the Rocky Mountains. Research Paper 41, 17 pp., illus.

Presents preliminary board-foot and cubic-foot aerial volume tables prepared from 168 randomly selected Survey field plots, together with some tests of these tables on individual field plots not used in the table. Discusses use of the tables in plot measurement.

MOESSNER, KARL E. How important is relief in area estimates from dot sampling on aerial photos? Research Paper 42, 16 pp., illus.

Presents results of a study of the theoretical bias introduced by sampling directly on aerial photos in mountainous areas. Data indicate that proportions obtained from samples located by photo center did not differ significantly from those obtained when samples were located by map.

MOESSNER, KARL E. Relation of minimum area standards to proportions obtained by dot samples on aerial photos. Research Paper 44, 13 pp., illus.

Presents results of a study comparing proportions obtained by sample plots varying in size from one-fifth acre to 40 acres. Indicates a significant overestimate of forest land was obtained when large sample plots were used in predominantly forest areas having many small mountain meadows. When the strata sampled occurred both in large and small size tracts, the proportions obtained did not differ significantly by plot size. Also indicates use of large plots significantly increases the cost of sampling on aerial photos.

MOESSNER, KARL E., and EARL J. ROGERS. Parallax wedge procedures in forest surveys. Misc. Pub. 15, 24 pp., illus.

Describes and demonstrates use of the parallax wedge in making measurements from aerial photos. Indicates applications to a variety of problems in forest survey.

ORR, HOWARD K. Effects of plowing and seeding on some forage production and hydrologic characteristics of a subalpine range in central Utah. Research Paper 47, 23 pp., illus.

Reseeding and protection from grazing for 3 years achieved substantial improvement in quality and quantity of subalpine-herbaceous forage on parts of the Manti Canyon range rehabilitation project area. Further improvement, particularly in storm runoff and erosion control, is expected within the next few years.

PACKER, PAUL E. Intermountain Infiltrometer. Misc. Pub. 14, 41 pp., illus.

An illustrated manual describing an infiltrometer apparatus developed by the author and used in several studies in Utah and Idaho. Includes specifications for construction and gives directions for operation.

PLUMMER, A. PERRY, ROBERT L. JENSEN, and HOMER D. STAPLEY. Job completion report for game forage revegetation project W-82-R-2. Dept. Inf. Bul. 31, Utah State Dept. of Fish and Game, 128 + vi pp.

Information on forage production, rate of survival, adaptability of species tested to various sites, and preliminary results of superior strains of browse species for artificial revegetation is reported.

STAGE, A. R. Speedy scaling of low-value log-loads. Research Note 50, 4 pp., illus.

Measurements of load circumference, length, and number of logs were related to load volume as a way of scaling long-log pulpwood at a cost and accuracy commensurate with the value of the product.

WIKSTROM, JOHN H. Lodgepole pine--a lumber species. Research Paper 46, 17 pp., illus.

Lodgepole pine, a soft-textured softwood, has the properties to make good lumber. Production of lumber from this species is increasing. Because lodgepole pine trees are small, they produce a high proportion of narrow boards; difficulty of marketing these narrow boards imposes a handicap on the species.

WILSON, ALVIN K. A new high in Montana Christmas tree shipments. Research Note 44, 4 pp.

Montana Christmas tree shippers set an all-time record in 1956 by exporting nearly 4.2 million trees to markets in other states. Substantial increases over 1955 shipments occurred in all the principal tree-shipping counties. Eighty percent of the total shipments were by rail.

WILSON, ALVIN K. Northern Rocky Mountain pole production continues climb in 1956. Research Note 49, 4 pp.

The Montana-north Idaho-northeast Washington area produced 577,650 poles in 1956, an increase of 96 percent over 1955 production. Lodgepole pine, with 41 percent of the total, was the leading species, followed in order by western redcedar, western larch, and Douglas-fir. 1956 production was the third highest for any year since 1947. Western redcedar was displaced as the leading species for the first time since 1947.

WILSON, ALVIN K., and GORDON H. GREENWAY. Costs of logging virgin ponderosa pine in central Idaho. Research Paper 51, 15 pp., illus.

Data collected from a timber sale on the Boise Basin Experimental Forest relate logging costs to several variables including two logging methods, two marking methods, and two levels of reserve stand volume in the virgin ponderosa pine type of central Idaho. Tables show the distribution of logging costs for a reasonably typical operation in terms of man- and equipment-hours per M board feet and as percentages of the total cost of logs delivered to the mill.